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Quantifying time in minutes it takes to obtain a ladder-climbable deck in the online Collectible Card Game Shadowverse

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BACHELOR THESIS

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Abstract

The time that it takes to get a competitive account in an online collectible card game (or CCG) is hidden behind a lot of hidden play time. In order to bring light to the play time that is necessary to obtain the subset of items necessary for an account to be able to climb in a *Ladder-based* system, this study measured the time necessary to obtain these items and what the best strategy is to obtain such a subset of items.

The most interesting observation made with the time to obtain a deck, is that the decks that are the easiest obtainable are decks that have a very aggressive strategy. The hardest to obtain decks require cards that have a lot of impact in the late game. Therefore, the cards are generally much more expensive in decks that have as an initial goal to drag out the game.

Generally, it is concluded that Shadowverse requires at most an hour and a half in order to obtain a deck that can be used during ranked play in either *Format*, given that the player is informed of the quickest method via a guide to obtain the necessary cards and that the player is able to do so quickly. If this is estimated to be an average player, the average player should be able to have access all of the *Game modes* within an day of playing the game.

The total accumulated time is the total time a player plays in-game. The time spend on just playing the game, in Shadowverse's case, will be climbing the *Ladder* system. This means that the percentage of time the player needs to obtain the deck is very small compared to the time the player can use the deck to climb the *Ladder*. The time to obtain a deck will be about 0.18% of the total accumulated play time, given the functional assumption that the player is skilled enough to have an at least 50% win rate. Even when this is not the case, the ratio will only further improve, as the player will take longer to reach the highest *Rank* on the *Ladder*.

The explanation for the italic terms can be found in chapter 3.

1 Introduction

With the rise of gaming, the concept of a collectible card game and its success has already proven itself to be a viable, permanent and profitable model. This model, by extension, has been ported to the gaming space, where multiple games have taken this concept from either, their existing card game, a modification of their existing game or made a fully new environment for players to battle against each other.
Shadowverse is such an online collectible card game (or CCG), in where a player builds a deck of cards to battle opponents. This is similar to games, such as Hearthstone, Magic: the Gathering Arena and Yu-Gi-Oh! Master Duel.

1.1 The problem

The biggest issue with online CCGs is the incremental play time that is hidden to the average player. Playing the game each day for half an hour on will already accumulate to about total of a week of non-stop playing. Not to mention the fact that a lot of games require a specific subset of items in order to get an account that is viable in all play modes of a game.

In most scenarios, this would imply that the user would put in some time each day, accumulating play time a lot each day in order to achieve this goal. As stated by Frommel and Mandryk (2022):

> "Our findings suggest that there is variety in how players experience engagement rewards. For many players, these rewards were associated with positive experiences such as enjoyment, motivation, and a sense of achievement, and their natural completion was associated with intrinsic motivation and harmonious passion. In contrast, these rewards could also be detrimental by eliciting negative experiences when players miss out and could even be perceived as an obligation to play. Players' tendency to acquire rewards just for sake of the rewards was associated with more externally regulated motivation, more motivation, and more obsessive passion for play." [FM22]

In order to get a better view of this, this study wishes to answer a question with an existing methodology in order to compare games with the first step that always exists in online competitive Player-versus-Player games.

This Bachelor's Thesis is supervised by Giulio Barbero and Mike Preuss , will explain the relevance of the model in the industry, the in-game mechanics and terminology, the analysis of the model and the methodology used and conclude with a conclusion about Shadowverse's play time distribution.

This will be done by doing a regression over the overall model with quantitative and categorical data. With the time to obtain the necessary set of items as the regression target number. Then the weights and coefficients will be explained as best as possible in order to gain an understanding of what the best strategy is in Shadowverse to obtain a *Ladder-climbable* deck. Hence, the research question is devised as:

What is the time in minutes it takes to obtain a *Ladder-climbable* deck in Shadowverse?

2 Related work

When looking at the current market environment, developments within the industry over the following relevant concepts have to be referred to and explained in detail. This is related to the scientific exploration of Shadowverse specifically, as they are directly related to Shadowverse's environment and explain a few concepts within this study, with previous work as a focus point.

2.1 Shadowverse

Apart from fitting all of the relevant and prevalent terminology that was already explained. In order to understand why Shadowverse is chosen instead of other possible online CCGs, the relevancy of Shadowverse's game as a whole is explained in this chapter in detail.

2.1.1 Live-service games

When it comes to the games as a service model [DW22] , the model is very new to the industry as a whole[Eli21] . With that, the "rise of a service paradigm"[SK10] model can be applied to the game of Shadowverse, which has constant updates over its lifetime and is a fully online platform. As Shadowverse requires constant internet connection and using micro-transactions as the main source of revenue.

As stated in the problem description, the problem that arises with these micro-transactions and many different currencies, is that the overall overview, and the methods to obtain in-game functional elements, is obfuscated and very hard to understand for a consumer to interpret the game as a model[Hir04] . This makes estimating the time it takes to get an in-game functional element very difficult for the consumer.

In order to get a bigger picture of this exact problem, listed below are concepts and subjects that are involved with how Shadowverse acts as a live-service game.

2.1.2 Freemium model

Due to the rise, development and increased usage of the freemium model strategy, also going under the name 'free-to-play', which is implemented as a monetization model in the development of the gaming industry[FZD+22]. As a contrast explained is the more traditional model named 'pay-per-play', where the game is bought only once and there are no other monetary transactions after the initial purchase. Shadowverse implements this model and is freely available on IOS, Android and PC.

A big factor is explained in the chapter "Optimal adoptions of freemium version and patching strategy: Network and security externalities", in the *Journal of Management Science and Engineering* [HHK20a]. Where Hamari, Hanner and Koivisto (2019) explain that:

> "For one thing, when the patching incentive mechanism is adopted, the price of the commercial software can be increased under certain conditions, and removed from the adverse impact of the negative security externality."

Patching meaning the continuous updating of a game, after the official version was launched. This adding a constant stream of content, and with that, essentially making a game that can be played forever.

At first, this might sound contradictory for a sales model, however, as most users will continue to play the game over a long period of time, the time span that a user can be spending actual money increases. As the number of patches increases to the game, the user will become a continuous revenue stream.

This means that live-updates can create an environment where Riekki (2016) states in the paper *Free-to-play games: What are Gamers paying for?*:

> "Players are most often satisfied about their purchases and those that are not, will likely not develop into long-term core gamers. Players were likely to spend large quantities of money in their games to bot increase their satisfaction and to support the game's developers. The games themselves tried to provide content that offered the player with content that helped the player play the game and to succeed and content that could be used to be distinguished from the other players."[Rie16]

Shadowverse implements both content that helps the player play the game and content that distinguishes the player from other players.

2.1.3 Non-functional items

To emphasize content that distinguishes the player from other players that users can buy in a freemium live-service model such as Shadowverse, the non-functional items, or so called 'cosmetics' are a relatively new, but integral part of the gaming industry.
The reasoning for this is given in the *Journal of Business Research* about the industry as a whole, where Wang, Luo and Li (2022) state that:

> "Free-to-play games are increasingly reliant on the sales of non- functional in-game items to generate profits. In integrating social comparison theory and social norm literature, the current study is among the first to investigate the effect of peer influence on non-functional item purchases. This study identified envy and conformity as two vital mechanisms that mediate peer influence."[WLL22]

And to emphasize the envy and conformity that players feel when faced with non-functional cosmetic items in-game, the social motivations are explained in *Computers in Human Behaviour*, where Marder, Gattig, Collins, Kietzmann, Pitt and Erz (2019) state about the popular game League of Legends (or LoL) that:

> "As expected, given the nature of non-functional items, hedonic and social motivations were dominant. This prominence of social motivations, we believe, is linked to the fact that LoL is at its core a social game. Although purchases may have been primarily driven by a specific motivation, players may purchase items for a combination of hedonic, social, and utilitarian reasons."[MGC+19]

This means that the games' environment already exercises peer pressure on the player from the start, where the player wishes to distinguish themselves from other players. The fact that there are a lot of hedonic and social motivations for players to purchase these non-functional items, and by extension, a lot of ways to cater to these players players, makes it such that non-functional items are a great model to monetize games and the model itself is only developed recently.

When a player purchases any type of in-game content the effect this has on the player is explained in the *International Journal of Information Management*. Where Hamari, Hanner and Koivisto (2019) conclude the following:

> "Indeed, we found support for this "demand through inconvenience" hypothesis proposed in this study, indicating that the more enjoyable the players perceive the service to be, the more they are willing to use it, however, the less they are willing to purchase premium content. Secondly, as expected, social value was found to be positively associated with purchasing game content. Thirdly, the quality of the freemium service interestingly does not seem to be associated with purchase intentions. Fourthly, the economical value of the freemium service did indeed have a positive association with the intention to continue using the freemium service, but it had no direct association with intentions to purchase premium content. The economical value only had an indirect association with purchases through the increased willingness to continue using the freemium service."[HHK20b]

Therefore, it can be surmised that any purchase has a very positive influence on the games' further development as a whole. To highlight the importance of this statement, directly related to the revenue a game makes, it is stated in the journal *Business & Information Systems Engineering* by Voigt and Hinz (2015) that:

> "Our data has shown that digital freemium businesses operate in an environment with very heterogeneous users: in one case, 1 % of the user base accounted for almost 85 % of total revenues. This makes clear how important it is to identify high-potential customers as soon as possible and to give them preferential treatment."[VH15]

This gives an extra method for the developers of the game to be able to cater to the top 1% of players. As the social values incentivise that the user is pressured into buying non-functional items by having seen them in-game and wanting them due to the reason stated above and creating a positive feedback loop for the games' monetary environment.

2.1.4 Shadowverse's online presence

The exact statistics of Shadowverse's user size is not very well known, as this is information that has never been published publicly. However, Shadowverse is extremely popular in Japan, taking about half the trend space as seen in figure 2. Important to note with this, is that Japan has the third largest mobile game market [Fam].
Next to this, the estimated players is about 2.3 million and an average of 124 thousand players at all times [Ltd23]. Shadowverse claims that it has over a million total daily players. Whether this is true or not is not verifiable without confirming this is true. Assuming this is true, this means that there is a substantial player base supporting this game. [App23] [Goo23]

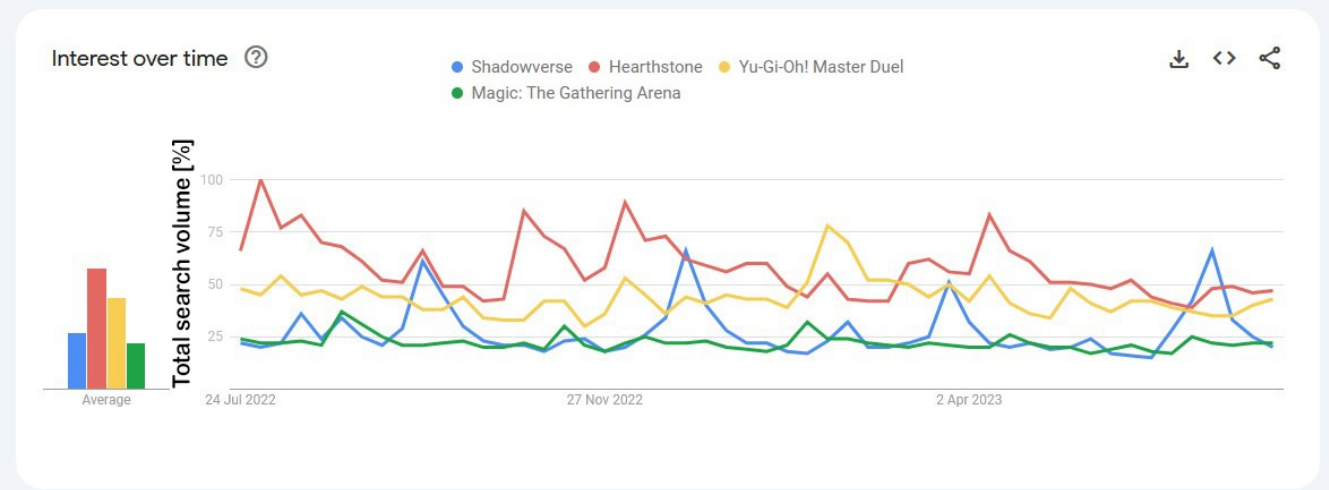


Figure 1: Total interest search volume of the most major online CCGs.

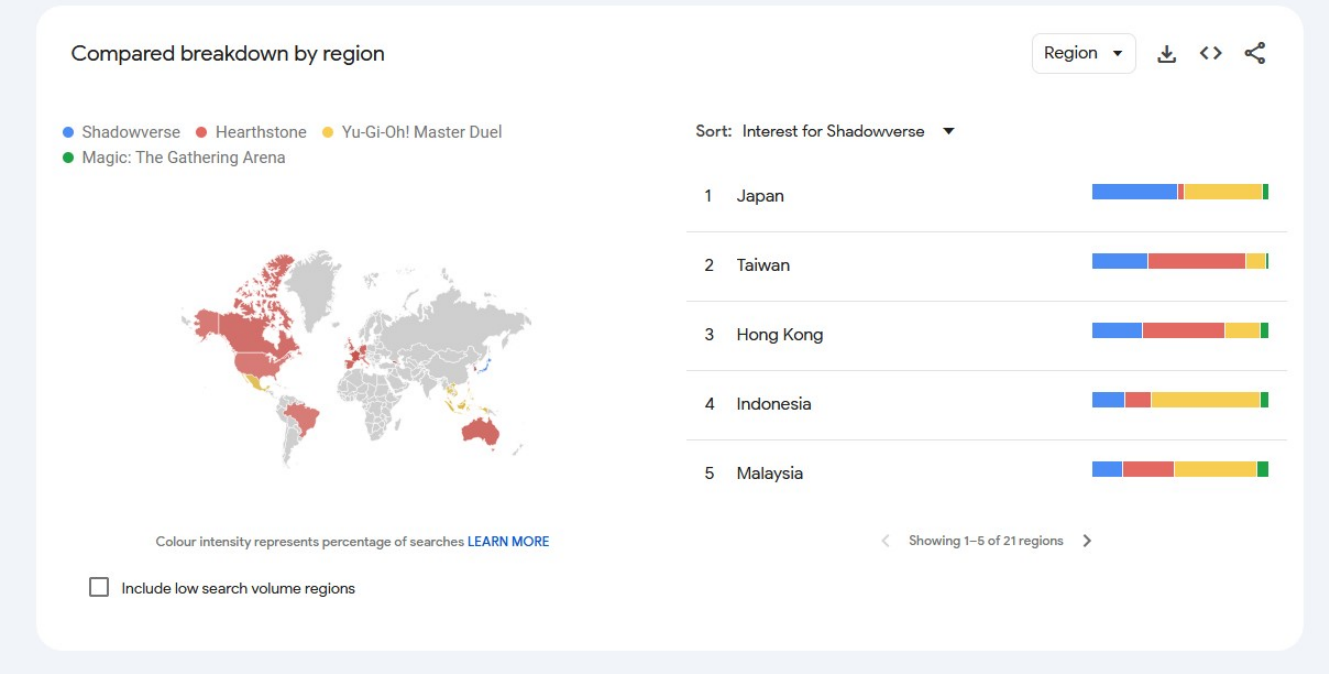


Figure 2: Topographic map of total interest search volume, with listed top 5 countries for Shadowverse.

As of the writing of this thesis, when comparing the daily average players from the last month to other online CCGs, Hearthstone has about 350 thousand players [Aut22a], Magic: the Gathering Arena has about 375 thousand players [Aut22b]
and Yu-Gi-Oh! Master Duel has an estimated 450 thousand players. [Aut22c]
Assuming that the only given estimate of 124 thousand players is correct, it means that Shadowverse is a bit bigger than a third of Hearthstone. Thus, with the continuous growth and development of the game [Cyb23] and, as seen in the trend chart below 1, being much more popular in especially

Japan and East-Asian countries, makes Shadowverse currently be in about the same ballpark as Hearthstone is when it comes to the worldwide economic space. Shadowverse also takes almost half the market space in Japan with Yu-Gi-Oh! Master Duel seen in figure 2.

This makes Shadowverse a proper contender in the online CCG market space. This, next to the proven to be profitable model that Shadowverse has implemented, proves that Shadowverse will be here to stay.

2.1.5 Deck-building limitations

Next to being a competitor on the global market, there are some more logically explicit reasons why Shadowverse was chosen in this study over other CCGs, such as the ones mentioned in the chapter above. To start off the reasoning for this, the concept of building a deck with limitations needs to be explained in depth. The limitations of building a deck in Shadowverse are as follows:

- Each deck has a name of a subset associated with it. The set of names is called the *Crafts* of the game. This is explained more in detail in chapter 3.
- Each deck has another subset or is the set of the *Crafts* subset, which is named by a *Format* associated with it.This is explained more in detail in chapter 3.
- Each deck consists of exactly 40 cards, taken from the associated subsets in each *Format* and *Craft*.
- Each deck may only contain three of the same (exact) card name at most.
- Each deck needs to have all cards in the player's collection in order to be used during a *Ranked match*.
- Each deck may not contain any of the banned cards.

The first observation, is that there are a lot more limitations compared to some other CCGs. Yu-Gi-Oh! facilitates a minimum of 40 and a maximum of 60 cards in the deck, next to having an up to 15 card extra deck and Magic: the Gathering only has a minimum of 60 cards. Hearthstone is very similar to Shadowverse when it comes to limitation in deck-building. The only big difference is that the deck size is 30 and the maximum number of cards that are allowed of the exact same name is 1 or 2 (1 for legendary, otherwise 2).

The biggest issue with an analysis, are the total permutations a deck has. As each permutation has to be included in the analysis. This is much more difficult if there's a range of cards that a deck can have, as in the case of Yu-Gi-Oh! and Magic: the Gathering. Next to that, Yu-Gi-Oh! and Magic: the Gathering rarely have rules that exclude a card from being included in any deck. Whilst this is true for a small subset of cards in Hearthstone and Shadowverse, this subset is almost the entire legal set in Yu-Gi-Oh! [Kon23] and Magic: the Gathering[otC23]. This means that for games, such as Hearthstone and Shadowverse, a case study as such is an optimum in relevance and complexity, where the permutations are relevant and have relevant variations in the data set, but the limitations make it such that the permutations are not possibly endless.

2.1.6 E-sports

After concluding that Shadowverse is a very complex CCG, despite having less permutations than other CCGs, the introduction to e-sports was a very logical next step. Following Magic: the Gathering Arena and Hearthstone in their footsteps, Shadowverse has had a very successful debut in the e-sports environment.

The current statistics on the e-sports environment report that the highest viewership has been over one hundred million views[Gik21] and the total prize pool is around 4 million dollars[ESM23] . The highest earnings from one player have been over a million dollars [Ear23] . This means that the game is at least viable for e-sports players to attend and play the game competitively for a living.

2.2 Other related work

2.2.1 Magic circle

Now, to explain a bridge to the concept of the Magic Circle' and how the concept is able to be translated to an online CCG is needed to explain the reference in this chapter.

To quote the concept of the Magic Circle as explained by Brown (2015):

> "In the context of games, the magic circle is the area within which the rules of the game apply, a special space, ideally but not necessarily demarcated by the rules within which play occurs." [BD15]

In the context of this paper, the Magic Circle is formed when the games' player wants to achieve a particular goal in the game. The goal proposed in this paper is winning the match fighting against either the player or computer. In order to obtain this goal, the player will need a deck that has a win rate that is at least above 50%.

To form a bridge from a player perceived goal to the immersion space of the Magic Circle in the game, an explanation is warranted to understand the logic from a player's perspective. The goal formed by the player in their mind, is to obtain a set of items in a game. By extension, after having collected these items, the player has achieved obtaining an account that can effectively compete in the game. The player will need to get familiar with how to obtain a subset of currency such that the items are obtainable in the least possible time. The way to obtain these items are strictly rules based from the currency obtained. The construction of the subset from this currency adds another complexity layer of optimization for the player. This means that the player will try to optimize the set of rules given at the start to obtain such items.

The explanation on why players will mostly fold to more unfair rules or even want to interact using the rules set in Free-to-Play games, is explained in the paper *Cash Trade Within the Magic Circle: Free-to-Play Game Challenges and Massively Multiplayer Online Game Player Responses*, where Lin and Sun (2007) concluded that:

> "This explains why they generally ignore complaints about game legitimacy and fairness."[LS07]

When comparing Pay-per-Play versus Free-to-Play players. In fact, the Lin and Sun (2007) even state that:

"Playerswho believe fairness is damaged in free games may not complain to game companies or managers based on their collective perception that "this is a free game, what can you ask for?" The idea of "take it or leave it" is gaining strength under the influences of free market logic or player-to-consumer identity transfer."[LS07]

2.2.2 The coupon collectors' Problem

The original problem for the coupon collector's problem is stated in *The collector's problem with group drawings* by Staadje (1990) as:

"We consider sampling with replacement of equiprobable groups of a fixed size m from a finite population S. Given a subset $A \subset S$, the distributions of (a) the number of distinct elements of A in a sample of size k and (b) the sample size necessary to obtain at least say n elements of A are given. Neat formulas are given especially for the expected values of these, as well as of some related random variables. Further we derive an optimal strategy to collect all elements of S under the assumptions that sampling one group costs α monetary units and that it is possible to purchase the elements which are missing at the end of the sampling procedure at a price of $\beta > \alpha/m$ per element."[Sta90]

With the coupon collector's problem modified for a card game, Richard (1995) states the problem as:

"The company includes a picture card of a famous baseball player in each pack of bubblegum it sells. A complete set of cards consists of ten players. The distribution of the cards is uniform; that is, a pack of gum is just as likely to contain a picture of any one of the ten players. How many packs does someone have to buy, on the average, to get a complete set?" [Ric95]

The solution is also provided in the respective paper to solve the amount necessary to solve the problem in the problem. The modification of the problem is also possible for each different type of coupon, as cards have different odds of being pulled from packs in Shadowverse.

The biggest issue is actually that an average CCG player would only want a specific subset from the total set and not the whole set with each *Card pack*. Next to that, there is the distinct possibility that for opening specific *Card packs* the player should switch the model to a different deck, because of the subset pulled due to that deck being more complete this way.

And the problem is not even done; after having a specific subset from *Card packs* and determining which deck the player wants to build, selecting which variation of the deck to build and which format makes many more complicated permutations that are already out of the scope of this Bachelor's thesis. Therefore, this new problem statement is a very interesting extension of the coupon collector's problem that warrants a new study in order to extend the model to how complete and what part of the subset would be able to be pulled from. Further details of this are given in the discussion chapter 5.

3 Terminology

There are terms and concepts in the internal game structure of the game Shadowverse that are necessary to understand, as these will be used throughout the paper in order to give clear, concise and specific distinction in the explanations given about the in-game mechanics and structures. The structure of how the game works and then the most important terms are explained below.

3.1 Deck-building restrictions

When building a new deck, the player has a choice in what legal card pool to use. Listed below are the choices that the player has to make in order to make a deck:

- Expansion
  An *Expansion* is a set of cards with a name and a theme associated with it. Each time there is a new set of cards released in-game, the set is called an *Expansion*.

- Format
  The player has a choice between *Unlimited* or *Rotation*. This is the choice whether the player wishes to play with all existing *Expansions*, and a banned/restricted cards list, or with only the five latest released *Expansions*, respectively.

- Season
  A *Season* depicts the currently legal set of cards that are legal in the *Rotation Format*. This is a rotating set. With each new *Expansion*, the oldest *Expansion* leaves the set of legal cards and the newest *Expansion* joins the legal set of cards. *Seasons* are named starting with the oldest *Expansion* name, a hyphen and then the newest *Expansion* name.

- Craft
  The player has a choice between *Forestcraft*, *Swordcraft*, *Runecraft*, *Dragoncraft*, *Shadowcraft*, *Bloodcraft*, *Havencraft* or *Portalcraft*. Each of these *Crafts* are a disjoint subset list of cards from the currently legal *Expansions*. There is one subset of cards, which are usable across all *Crafts*. These two subsets become a partially disjoint subset, making the subset the player can choose cards from to make a deck.

3.2 Ladder

The *Ladder* is a way for a 1-versus-1 competitive game to keep track of how well a user performs. In Shadowverse, there is two *Ladders*, one for each *Format*.

The score of a user is their position on the *Ladder*. The higher a user's position on the *Ladder*, the better a user's performance score. In order to rank up, a certain score must be achieved. A player increases in score when they win and loses score when they lose. With consecutive wins, a player can get more points. This will happen if the rank of the player playing in the current *Format* is lower than the other *Format*. A player will always increase their score when winning once and then losing once consecutively. This phenomenon is called *Ladder-climbing*.

The existing ranks are, in order: Beginner, D, C, B, A, AA, Master and Grand Master. The ranks are divided into sub-ranks denoted by a number except for the master ranking, where the number is a 0-3 and the higher this number, the higher the user's rating in the sub-rank. The floors

and ceilings increase in range when the user jumps rank, meaning that the user will need more wins in order to increase their rank once again. The overview of all the ranks with floors and ceilings is shown in figure 3.

Figure 3: Ranks with floors and ceilings in the game.

3.3 Methods to obtain cards

3.3.1 Rarities

The *Rarities* in the game are bronze, silver, gold and legendary. Each of those *Rarities* has a chance to be animated. This animated card is called an animated 'x' where 'x' is its rarity. The animated card is worth slightly more than the same non-animated card with the same rarity. This chance is displayed in table 1.

3.3.2 Card pack

A *Card pack* is obtained by exchanging either a ticket, 100 rupies, 50 crystals or 100 crystals. The 50 crystal purchase being possible only once each day. By using a *Card pack*, eight cards are added to the player's collection with different probabilities from one *Expansion*.

The *Card pack* contains 8 cards of varying *Rarities*. The exact probabilities are shown below in table 1:

Card	Rarity	Probability
1 through 7	Legendary	1.5 %
	Gold	6.0 %
	Silver	25.0 %
	Bronze	67.5 %
8	Legendary	1.5 %
	Gold	6.0 %
	Silver	92.5 %
For each of all 8	Animated	8.0 %

Table 1: *Card pack* Probabilities.

3.3.3 Temporary deck

A *Temporary deck* obtained by exchanging a ticket for the deck. A *Temporary deck* ticket is always given for free when the user completes the tutorial or when a new *Expansion* launches. The cards are removed when a new *Temporary deck* is released.

3.3.4 Vials

Vials are obtained by a player, when the player permanently removes cards from their collection. The amount of *Vials* the player gets for each card depends on their rarity and whether the card is animated or not. The amount of *Vials* in order to obtain, and that are granted when a card is removed, is listed in table 2:

Rarity	Cost to obtain	*Vials* when removed	*Vials* when removed & card was animated
Bronze	50	10	30
Silver	200	50	120
Gold	800	250	600
Legendary	3500	1000	2500

Table 2: Amount of *Vials* needed to make or obtained when remove a card is removed from the collection

3.4 Currencies

- Rupies/Rupy

  Rupies are the main currency to obtain in-game items. The currency is given out by completing quests and achievements. This currency is exchangeable for *Card packs*, some in-game non-functional items and entering the *Game modes*: *Arena*, *Open-6* and *Cups*.

- *Vials*

  Vials are the only currency that can be exchanged for new cards to be added to the player's collection permanently. This currency is obtained by removing cards permanently from the player's collection that the player currently owns. To note is that, it is more expensive

to add a card to a collection than to remove that same card. This typically means that multiple cards have to be removed from the collection in order to add one.

- Temporary Gems
  Temporary gems are obtained by winning three matches in a match against another player that is not a *Private match*. Temporary Gems are exchangeable for temporary available cards in the store.

- Tickets
  Tickets are exchangeable for their explicitly listed function. This can be a deck, a *Card pack* or simply entry to a game-mode.

- Crystals
  Crystals are the premium currency that is only obtainable by spending real money. This premium currency is, however, exchangeable for almost anything in the game.

3.5 Game modes

A *Game mode* is an activity a player can participate in, whilst playing the game. Shadowverse has a few game-modes that the player can participate in. Listed below is each method to obtain currencies and what currency the method can obtain.
By completing achievements and missions in *Game modes*, the user is rewarded with an amount of a specific currency per mission and/or achievement. Progression to each achievement and mission is cumulative and both missions & achievements may progress independently from each other.

3.5.1 Story match

The user picks a deck to play against the computer. The difficulty of this mode is significantly reduced to accompany newer players through the new mechanics of the game. The user is rewarded with some cards, some non-functional items, *Vials*, rupies, arena tickets and *Card pack* tickets.

3.5.2 Ranked match

The main *Game mode* of Shadowverse. The user will be matched up against opponents of equal rank and preferably as close of a score to the player as possible. Temporary gems, *Card pack* tickets and rupies are possible rewards from missions/achievements.

3.5.3 Arena modes

The *Arena modes* are a way for a player to play the game without needing to build a deck beforehand. The user will either make a deck by selecting pairs of cards each time to build a deck (Take-Two) or open 6 *Card packs* and build a deck from that pool of cards. The minimum reward for this is one *Card pack* ticket, which is the measurement of all *Arena Ticket* in this study. Drafting and playing sealed is much more complex than copying and piloting a deck. Playing all five games would also drastically decrease the efficiency of an *Arena Ticket* compared to time.

From time to time, a *Cup* is introduced. A *Cup* has a *Format* associated with the legal cards that are allowed to be played in this *Cup*. The player has to win a three or four times against

randomly paired other players to progress through two stages. The finals are double elimination until the player has achieved five wins against random opponents. If a player that wins the finals, their deck is registered in a curated list in-game.

3.5.4 AI matches

AI matches are like story mode, but the computer has more curated decks and the player needs to build a deck beforehand or pick from one of the listed decks in order to beat the computer. The rewards for beating specific harder match difficulty is 200 rupies per win per *Craft* per difficulty.

3.5.5 Private matches

Private matches are two players playing a game between each other. Compared to *Ranked matches*, these matches do not have a random player match up and *Private matches* do not give rating points for the player's *Ladder* score. A player can earn 100 rupies every time they finish a private match against a unique player, up to a maximum of twenty times.

4 Analysis

4.1 Data Collection

For this thesis, the data collection is very extensive. Due to the fact that an existing data set was not present, a new data set was generated for this study. The major source of this data set is the in-game curated list called the 'Tournament-winning decks' list, which can be found in-game in the deck creation menu. The original list is also supplemented with a few extra deck lists that were removed later from the in-game list. These lists are all unique with each additional *Expansion* and the reason for their removal was never stated. Nevertheless, considering the dominance of this deck, it would be not just to not include the deck. The decks in question are an archetype in the *Portalcraft Craft* that was incredibly overwhelming. The specific archetype is named 'Artifact Portal' and the deck to this day has an overwhelming presence in the *Unlimited Format*.

4.1.1 Deck collection

Each deck consists of a list of cards with variables and the following categorical variables:

- The legal *Format* of the deck (*Unlimited* or *Rotation*)
- The *Season* that the deck was playable in
- The *Craft* of the deck that it is associated with
- A name for the deck
- A total vial cost for the deck

The sample, that is available in-game, consists of all decks that either have won official tournaments or have won the finals of a so-called *Cups*. The term *Cups* is explained in chapter 3. The biggest difference is that for *Cups* players only need one deck to compete instead of three in tournaments. To have a players deck registered in the curated sample, the player must proceed towards the highest stages in a *Cup*. The player must also win five times in the finals to have their deck registered. Therefore, *Cups* need a much higher win-rate than in the normal ranked mode in order to win the finals. Users are able to copy these decks with little effort, provided they have the *Vials* to make these decks.

From this list, each deck is sorted per *Season* as a categorical variable, as each *Season* depicts a time frame in which a deck was playable. This time frame can depict which decks are able to climb the *Ladder* within the given period of time. The building of a new deck is necessary when a new *expansion* releases, because both *Formats* will have to adapt to the newest cards released. This can increase or decrease the in-game necessary time to build a deck. This trend can be seen in figure 10.

Next to collecting the data for the decks, the codes for each deck of the *Temporary decks* had to be brute forced from the database, due to these not being available anymore, unless the user still had the tickets to redeem them specifically.

4.1.2 Card data

Each deck consists of a deck hash. This is imported from the tournament-winning decks into SQL, stored together with the *Season*, *Format*, *Craft* and name of the deck. After this, the deck's metadata is fetched from the Shadowverse portal API[@th23].

Then, the amount of *Vials* is calculated for each separate deck. This is simply done by getting the sum of *Vials* of what each card costs in *Vials* to make.

By gathering all of these data points, each deck will have a necessary amount of *Vials* in order to make the deck. This gets reduced by the cards that are available in a *Temporary deck* if there exists a *Temporary deck*. Which, is a sample deck for an archetype of the current *Format* that is given out for free at the start of each *Expansion* or, when the account is created, for the currently active *Expansion*. This should make it that *Rotation* deck will become cheaper when the player is just starting out.

4.1.3 Time data

To get data on how long each unique activity takes, each activity is measured by taking game play footage and measuring the time it takes for that activity to complete. For any game actions that do not have footage (for the reason that it was never recorded), a rough measurement and then estimate will be taken on how long the action will take. The actions and rewards are also timestamped, as some methods and rewards were not available due to Shadowverse being a live-service game and the company has the data entirely privatized.

After this, each activity is sorted by reward over time in minutes to obtain these rewards. This gives a factor on how much of a currency a user would obtain per minute of in-game playtime. This currency is first translated to *Vials*. This is then sorted from highest amount of currency to

lowest. The reasoning for translating everything to *Vials* is simply that it is the last currency that is necessary for creating a deck and everything is convertible to *Vials*. As a consequence, this is usually done by using a chance function to convert 100 rupies to the total vial value from all cards in one booster that are the normally distributed average of millions of sampled boosters.

The following features from a deck are then stored in a .csv file: *Season*, *Format*, *Craft*, use of a *Temporary deck*, name, *Vials*, time in minutes, time in days. The time in days and name features are not used. In the case of days, due to the fact that it was always 0. In the case of name, a bag-of-word feature may be too over-fitting, as the data set is only $\tilde{1}800$ entries big and outlier detection that could be included if this feature would be used is not as useful, as the main goals of the regression is to have a possible explanation of what factors influence the time to make a deck. There exists a good chance that the name of new decks, or worse when only part of the new decks, may not match any of the current decks' names at all, making the trend estimation not as reliable.

4.1.4 Ranked matches

With *Ranked matches*, the point system works as follows:

- For each win, 100-150 points are given
- For each loss, 100-70 points are deducted

Winning consecutive matches will give more points if the rank in the other *Format* is at least the same. Winning from a higher rated opponent will give more points and losing to a lower rated opponent will deduct more points. When the player wins two matches in a row, extra points are awarded. The exact formula for this is not known, but on average, if a player would win 50% of the time, the very rough estimation is that the player will climb the *Ladder* by about $\sim$55 points per two matches.

4.2 Methodology

Ultimately, the achieved result gives insight in what game-elements have the biggest influence on the game time in minutes. In order to achieve this, a regression function will be trained on the features extracted from the data set that was collected.

However, in order to keep the scope of the experiments and observations within certain limits, there are a few points of discussion necessary for the analysis to make sense within reason.

4.2.1 Functional assertions

In order to fulfil premise to make the study reasonable for a bachelors' paper, a few points have to be asserted as true. These are stated with their explanations as follows:

- The user has made a new account.
  The goal of the study is to see how long it takes to make a deck from scratch.
- The user has read a guide and knows the quickest method to obtain the necessary materials to create a deck.
  This means that the goal of the paper is the same as the user.

- The win rate for all matches is 50%.
  This is likely not true and much higher, but, first off, it is impossible to measure as typical footage users winning (almost) all matches. Secondly, the win rate in order to climb the ranks to the highest rank has the be at least 50%. Next to that, the user likely has to take some time reading cards and building a deck themselves. Lastly, this is a rough estimate.

- Each *Card pack* will only contribute *Vials* instead of a chance to pull a card of each of the possible decks.
  This problem is an extension of the coupon collectors' problem[Ric95] and is very much outside of the scope of this thesis. Therefore, the problem is generalized by taking the median of received *Vials* a user would get from opening one booster.

- The user will have skipped the dialogue in the story mode.
  The goal of the user is to just obtain a viable deck as soon as possible.

- The two different types of matches are story line and ranked play.
  This is because *Story matches* are significantly different than online *Ranked matches*. There was not enough data to compare the different types of *Story matches*, so a significant amount of data points was gathered.

- The population distribution of the response variable that are the amount of *Vials* a deck costs is normal.
  Histogram shows this is roughly true, but it is mandatory to assume this for statistical regression.

- The standard deviation of the population distribution is the same for each group, with exception of a feature being able to make a significant difference. Denote the common value by σ.
  The overall σ has to be consistent in order to dismiss outliers.

- Samples from the populations are independent and identically distributed random samples.
  Statistically important.

Even with these functional assumptions, the goals of the paper are to have a method to get a predictably rough estimate on what influences the time to obtain one deck is met and to have a rough time estimate that is easily interpret able by the consumer for Shadowverse. Only one deck is necessary, as only one deck is required in order to play the *Ranked match Game mode*.

4.2.2 Experiment

From the deck's metadata, the total amount of *Vials* is calculated minus any cards that are available from the, at the moment, *Temporary decks*. One *Temporary deck* is freely obtainable at the start and, if a *Temporary deck* is used to discount the value, it is kept track of as a separate feature. The impact of *Temporary decks* will likely also be seen using this feature. Figure 4 shows the impact of using a *Temporary deck* on the total vial cost of a deck, using a double-box plot to highlight the difference between using and not using a *Temporary deck*. Noted is the fact that each average is lower and sometimes substantially lower than the cost of decks that do not have an available *Temporary deck* for their respective archetype. This means that the *Temporary decks*

contain generally useful cards for each respective represented archetype within the set of *Temporary decks*.

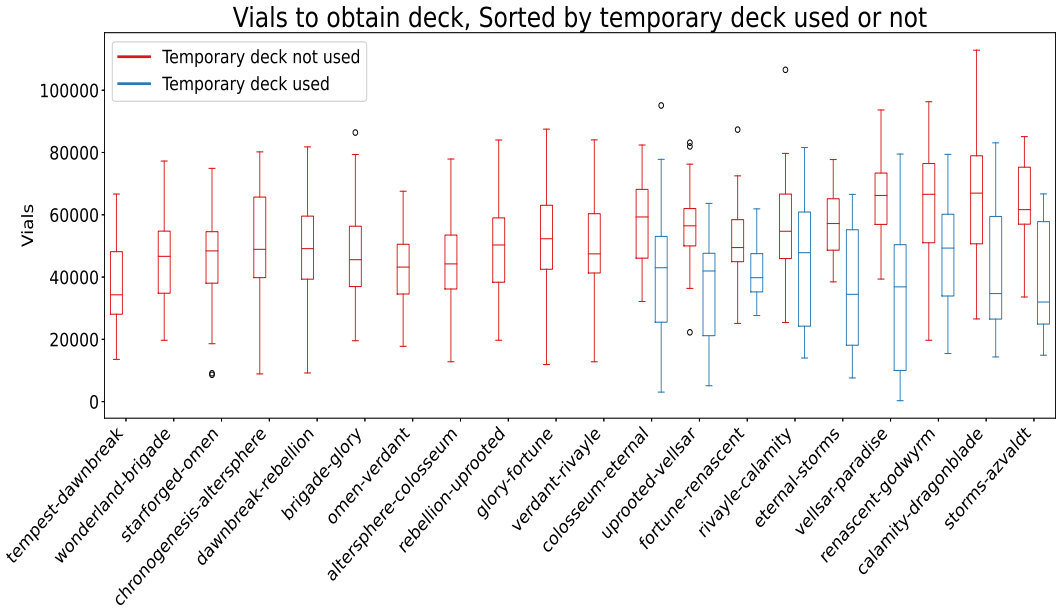


Figure 4: True value of *Vials* over all *Seasons*.

In figure 5 is a histogram to show the distribution of the vial cost of all decks. This may look like a normal distribution, which it almost is.

The average is relatively quite close to the median, 45733.77 and 46750 respectively. The mode, which is 56450, is the reason why the median is higher than the average. This means that it can be speculated to be a normal distribution with a thin-long right tail.

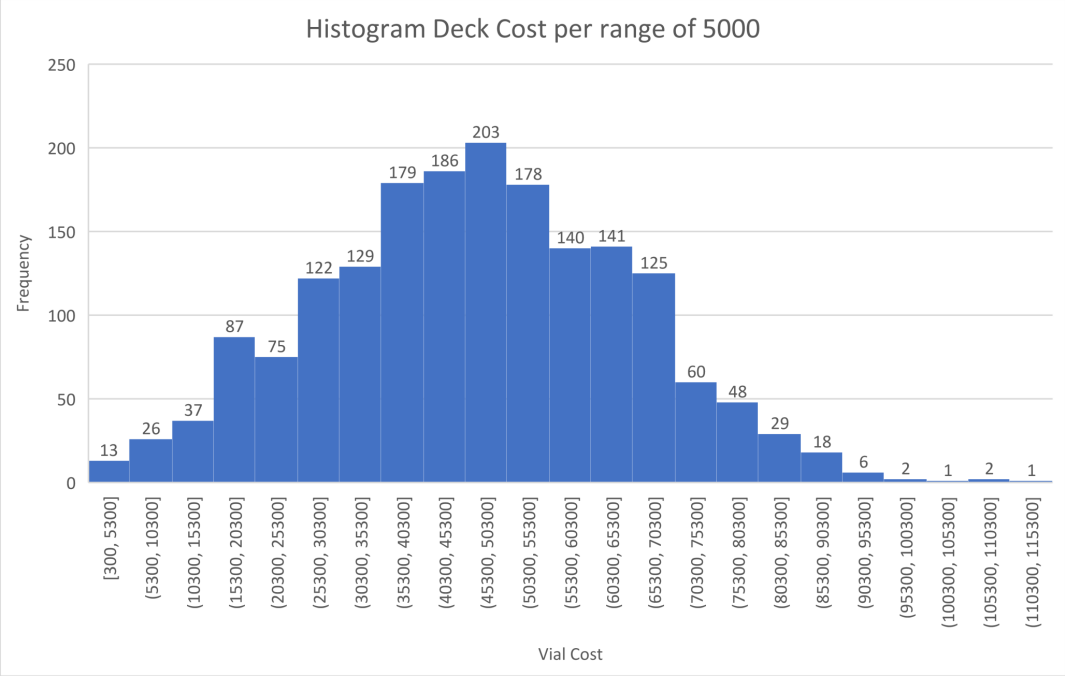


Figure 5: Histogram sorted per vial deck cost

First, all of the methods to obtain *Vials* are listed and their respective rewards in *Vials* are calculated, either by using a chance function to convert *Rupies* to *Vials* or by listing their direct rewards from performing specific in-game actions, and then sorting them by efficiency. Then, the time needed to create a deck is then calculated by taking all of the methods in order of which method gets the most *Vials* per minute of game time and deducting the amount of *Vials* this activity will give.

This is done until the amount of *Vials* is satisfied. The amount of minutes, together with the *Season*, *Format*, *Craft*, the use of a *Temporary deck* and name will be stored in a .csv file[Dan]. The relationship between the amount of *Vials* needed to make a deck and the time spend in order to obtain these *Vials* is plotted in figure 6, where the time that it takes to obtain *Vials* gradually increases.

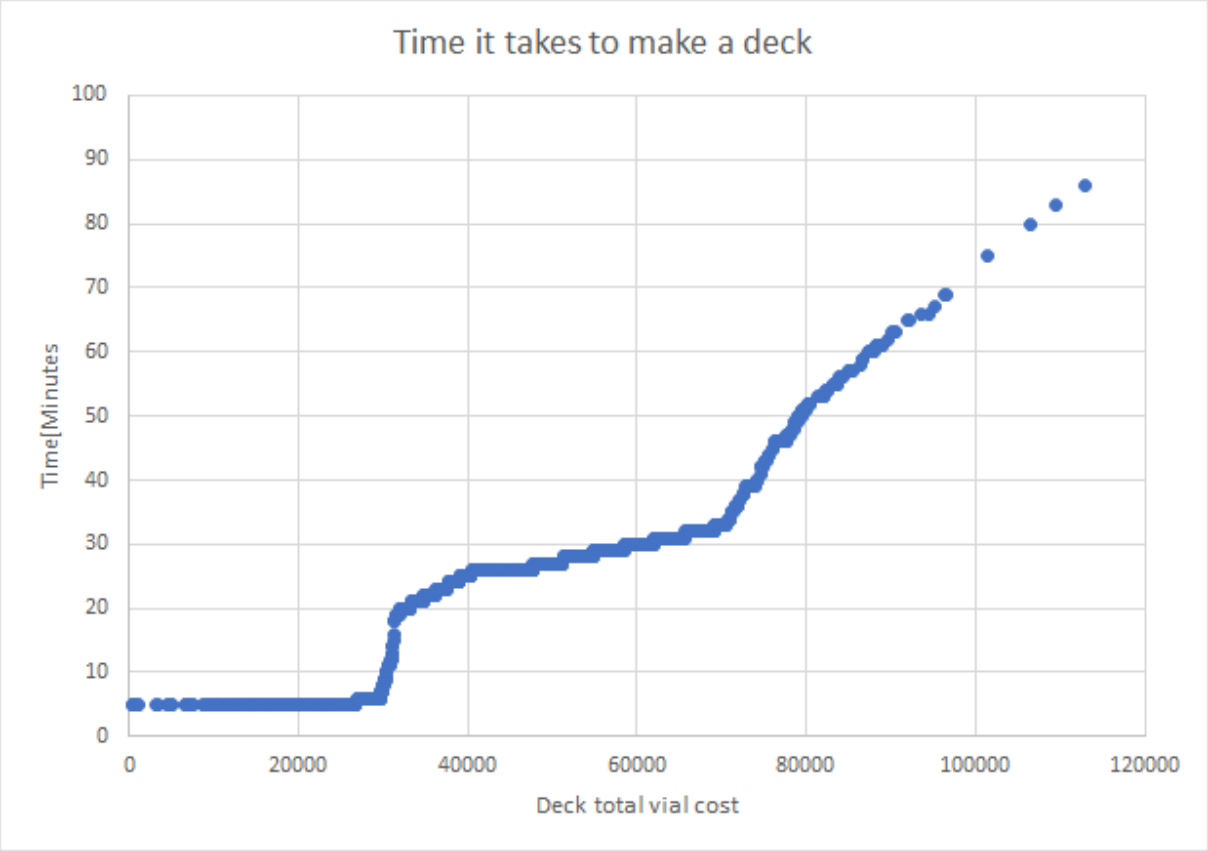


Figure 6: Relationship of total time in minutes
is needed to obtain a deck of a specific vial cost.

After the data is compiled, a regression function is trained with parameters:

Parameter	Value
Cross Validation Factor	2
Scoring	Negative Mean Squared Error
Type of regression	Linear
Encoder for categorical variables	HotOneEncoder
Categorical Features	Season, Format, Craft and use of Temporary deck
Quantitative Features	Vials when time is used as a target variable
	Time when vials are used as a target variable
Target Features	Time in minutes to create the deck and Vials

Table 3: Parameters used for the trained regression function.

The coefficients and features are extracted for interpretation and graphs will be drawn for all of the relevant weights. All of these elements are shown and explained in the next chapter.

4.3 Results

The regression was first run with the features *Season*, *Format*, *Craft* and whether the *Temporary deck* was used to subtract the vial cost. Then, the time in minutes variable or *Vials* variable, depending on which one is not the target variable, is added as an extra feature and then run again. This proved to substantially improve the root mean square error[Agr18].

The in-game time that matches take is also an observational result and an important element of estimation when it comes to estimating the time it takes to have a *Ladder-climbable* deck. Therefore, this will also be reported with the graphs and a chart in the appendix in order to keep transparency in the data provided, together with the source of all of the measured data.

4.3.1 Time taken to obtain one deck

Plotted in two graphs in figure 7 and figure 8 is the the amount of *Vials* needed to make a deck and the time it takes to obtain the amount of *Vials* necessary using the most effective method respectively. The graphs are separated into the two different *Formats*, *Rotation* and *Unlimited*, and plotted into two neighbouring box plots. This is, due to the fact that, because there is a substantial difference in the vial cost of an *Unlimited* deck and a *Rotation* deck. This is also shown in the regression trained weighted coefficients in table 6. The specific *Format* order is the release of each *Rotation Format* in chronological order from left to right. This makes a time trend line to draw observations and conclusions from for each *Format*. This trend line is then drawn using the average vial cost and time it takes to get that many *Vials* of each *Format* in figure 9 and 10 respectively.

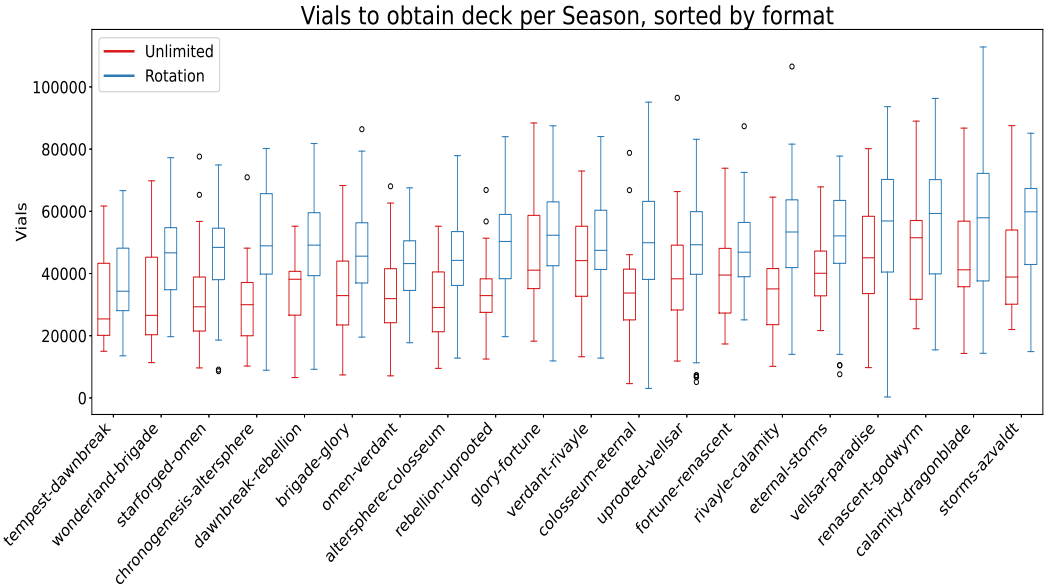


Figure 7: True value of *Vials* over all *Seasons*

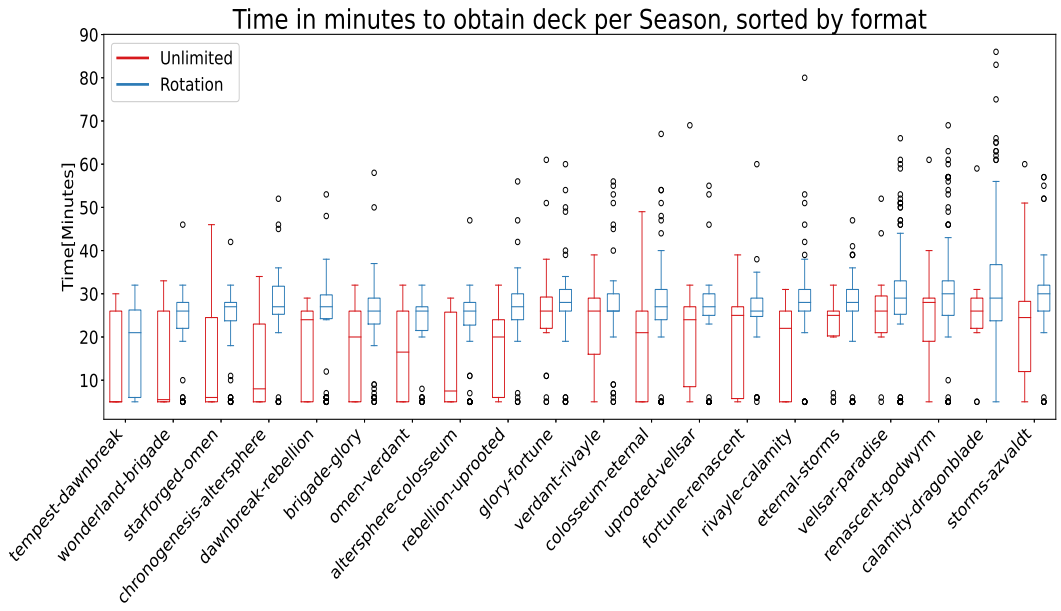


Figure 8: True value of time in minutes over all *Seasons*

The first observation is that the true value of *Vials* and the time it takes to obtain those *Vials* have a large standard deviation. There are also a lot of low outliers, specifically in figure 8. This can be attributed to the minimum time being five minutes, which is the time necessary to complete the tutorial. This sufficiency can be explained, as the *Vials* obtained using the resources provided at the start of the game already being sufficient to create a deck. In the case of the high outliers, the deck costs a lot more to build due to specific circumstances. These circumstances can possibly be explained with the regression formula to find the any correlation behind the outliers as found in 6 in appendix A, hence they are left in for that particular reason as well.

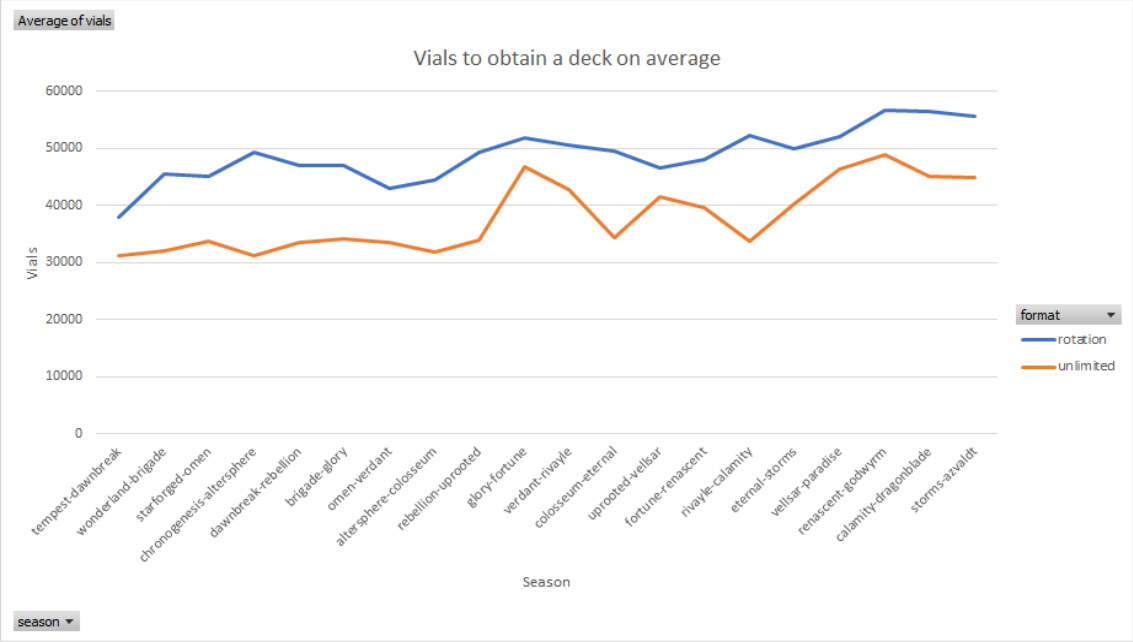


Figure 9: Average *Vials* per *Format* over all *Seasons*.

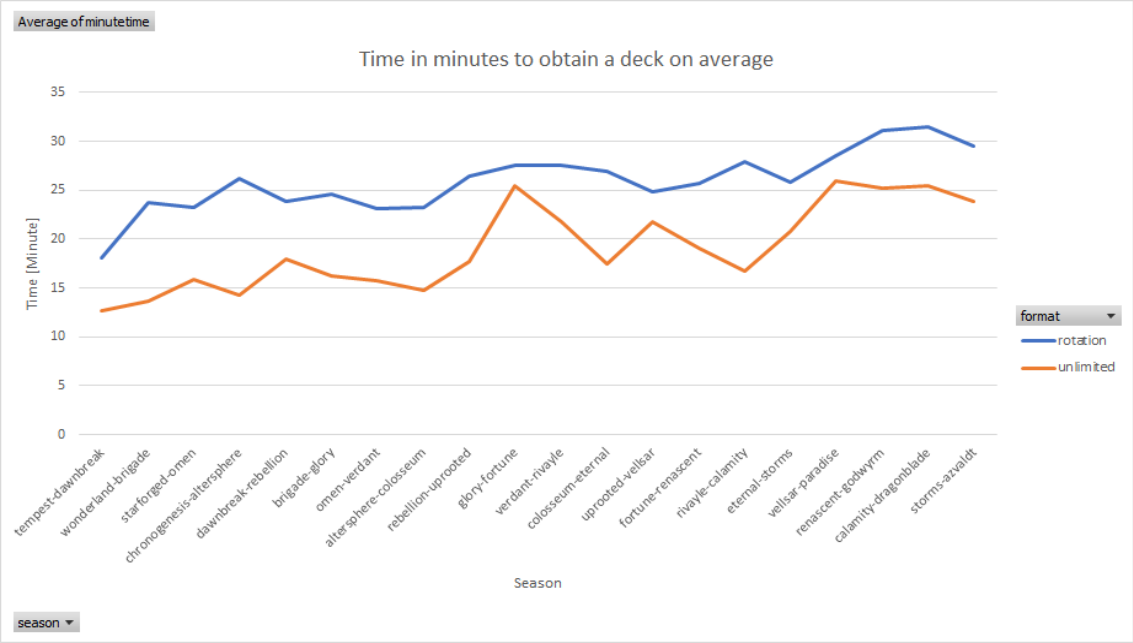


Figure 10: Average time in minutes it takes to obtain the *Vials* for each deck per *Format* over all *Seasons*.

The second observation is that there does seem to be a very slight increase in the vial cost over time. The most interesting part with this, is that the time to obtain the more expensive *Vials* has also increased slightly. The increase in time is about 10 more minutes compared to the first reported *Season*. A second interesting observation is that the *Unlimited Format* had a small spike in the vial cost and time around the *glory-fortune Season*.

4.4 In-game time data

The in-game time is recorded from loading screen to loading screen in order to have a consistent measurement. This is the time that a player would be playing the game. The time starts when the loading screen appears when starting a match until the loading screen appears at the end of a match. This is measured for *Story match* and *Ranked match Game modes* separately. As the two modes have different times. The unpaired and paired T-test, with and without assuming unequal variances, all give a two-tailed P variable at the highest in the order of magnitude of 10^{-8}. Therefore, the variables are considered separate as they are independent.

The statistical values for both the *Ranked match* mode and *Story match* mode are as follows; for the *Ranked match Game mode*, the sample size is 53, the average is 12.4588 minutes, the median is 12.8166 and the standard deviation is 3.3490 minutes. For the *Story match Game mode*, the sample size is 60, the average is 6.8033 minutes, the median is 6.3333 minutes and the standard deviation is 2.7879 minutes. This is put into an overview in figure4. The entire table of raw data can be found in the appendix in tables 7 and 8.

	Ranked match	Story match
Sample size [n]	53	60
Average [Minutes]	12.4588	6.8033
Median [Minutes]	12.8166	6.3333
Standard Deviation [Minutes]	3.3490	2.7879

Table 4: Statistics over the *Ranked match* and *Story match* s.

If the user has an exact 50% win rate and never gets a win-streak, the user would gain about 55 rating score in 2 games. In order to then eventually reach the rank of Grand Master 0, the user would need about 60.000 rating points.

$$\frac{60000}{55} = 1091$$

The number of matches is estimated to be 1.091 (rounded up as players cannot play less than one game). This means that the total amount of time that is spend becoming the highest rank in the game would be in the ballpark of:

$$1091 \times 12.34375 = 13467.03125$$

$$13,467/60 = 224.45052$$

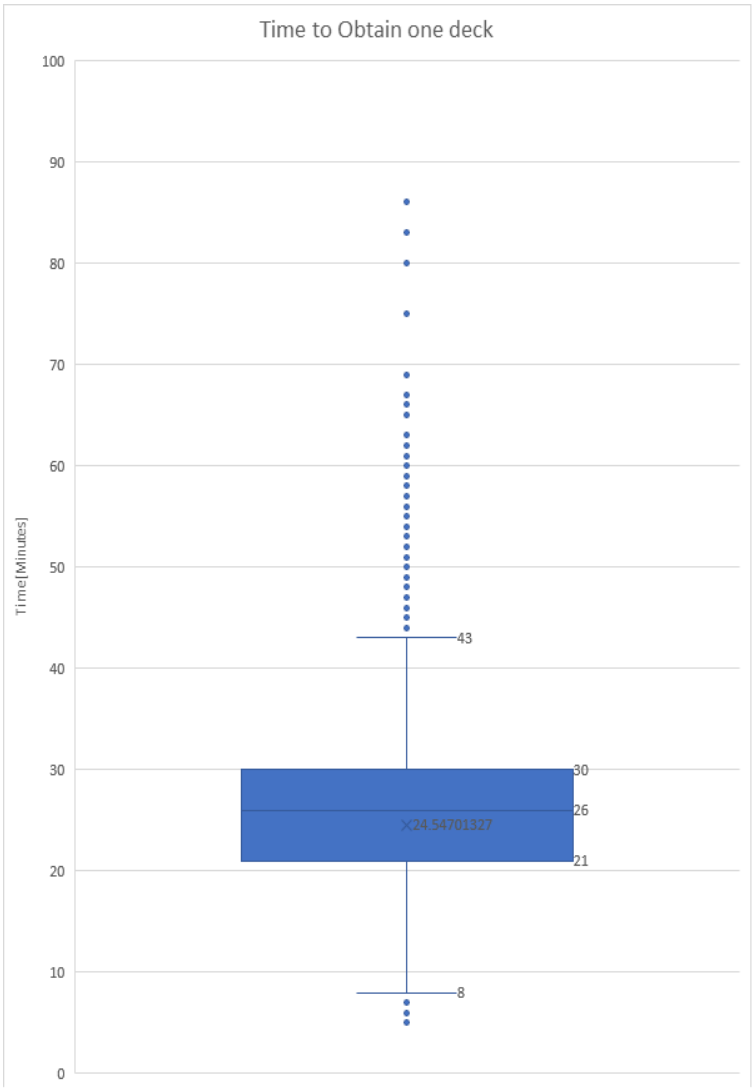


Figure 11: Box plot of time to take to obtain one deck

The total amount of time would amount to about 224.45 hours of in-game time. Compare this to the time to obtain a singular deck, which, if the user has read a guide and knows what they're doing, never comes above the 90-minute mark and is on average 24.5470 minutes, as observed in figure 11. Logically, the total amount of time that the user would be spending a deck, compared to the total playtime to reach the *Grand Master Rank* from a starting account would be about $24.5470/(13467.03125 + 24.5470) = 0.001819$. So about 0.18% of the total in-game time played.

The time it takes to complete the tutorial is about 5 minutes. This is the total time it takes for a player to start the game, skipping all the dialogue, the loading screens and the matches themselves. This excludes the time it takes for the game to update, which depends on the player's internet speed. Only the time that the player has been able to actually play the game has been measured for consistency. This estimate is a rough estimate and may have more variance than the other measurements performed in this study.

4.4.1 Temporary deck Feature

As mentioned earlier with the methodology in chapter 4.1.2, it is speculated that the *Temporary deck* feature highlights the possibly decreased cost of a deck compared to other decks in the *Rotation Format*. In order to see if this is true, the amount of *Vials* is plotted for the decks in the *Rotation Format* and then sorted if those decks used *Temporary decks* to discount the cost in figure 12. It is also clearly seen that the decks that use the *Temporary deck* (if available) are much cheaper, sometimes even cutting the overall cost of a deck by half of what other decks are, as seen with the two latest *Expansions*.

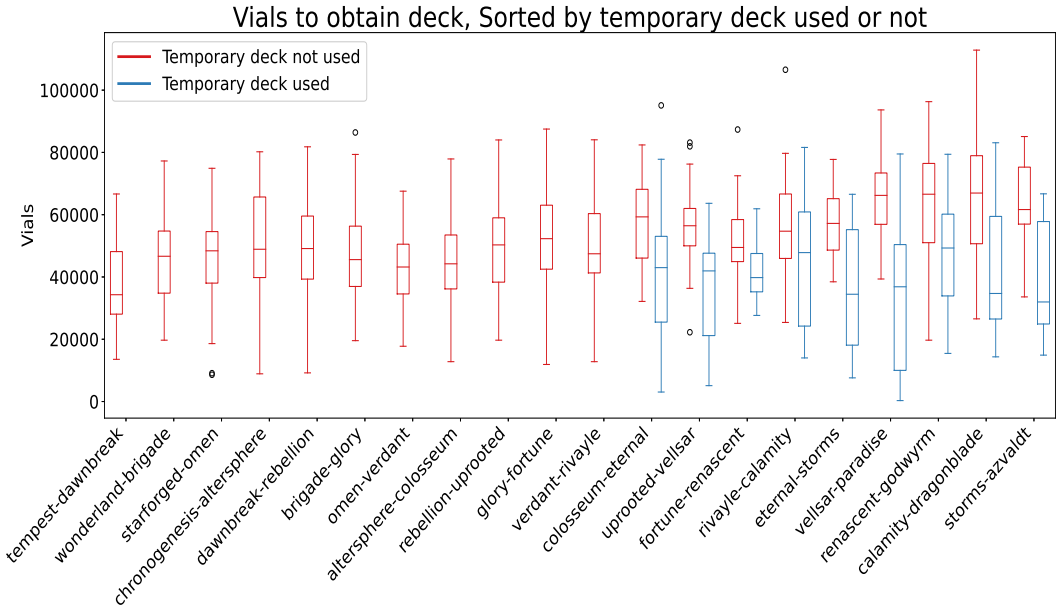
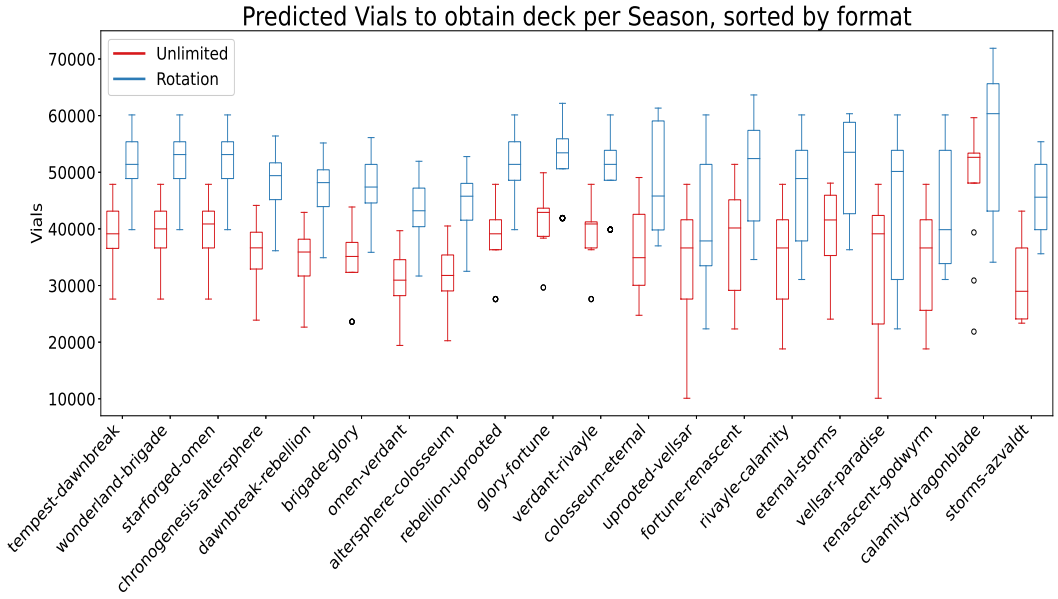


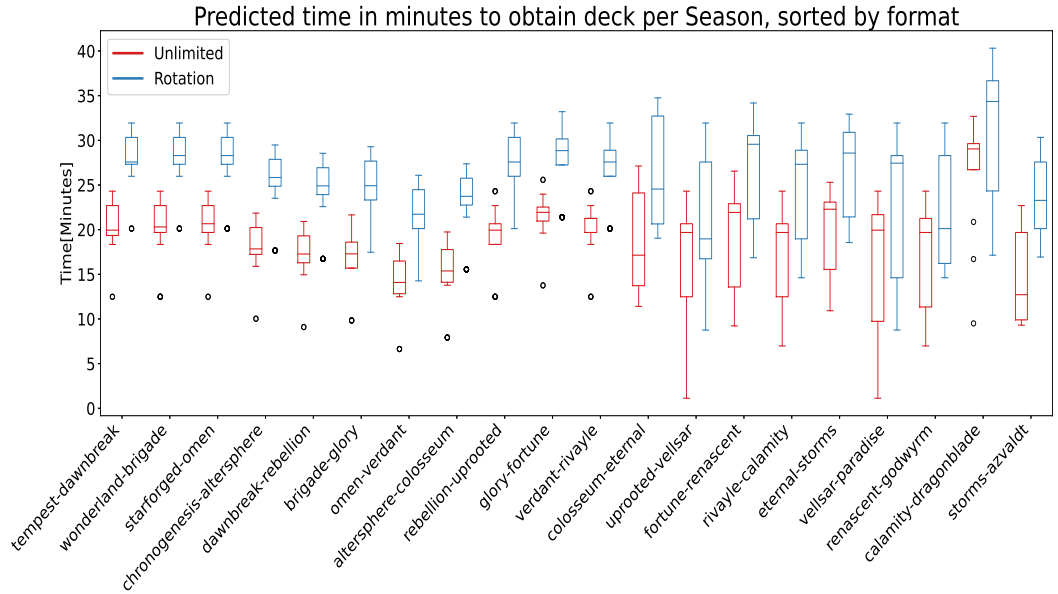
Figure 12: Vial cost of deck in *Rotation* with and without use of the *Temporary deck* feature.

4.4.2 Regression predictions

The best performing regression method is having the time in minutes as the target variable and using each unique *Season*, *Format*, *Craft*, use of *Temporary deck* and *Vials* as features as seen in table 5 with the performance data is given in root mean square error. . On the top axis, the target variable is given. On the left axis, the features are listed. However, the first runs on the linear regression algorithms did not use the quantitative features, which are the figures in 13. This was first to see, if the linear regression would be able to produce a function that would be able to fit the true values. Seemingly the predictor has had trouble to predict properly and that's where the quantitative variables helped a lot, as seen in the figures in 14.



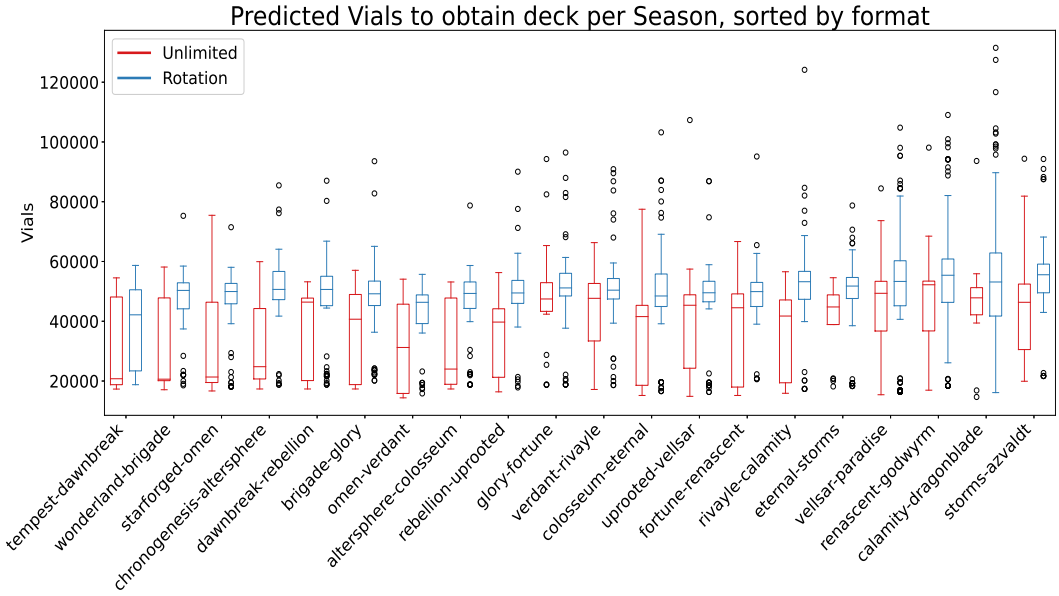
(a) Predicted *Vials*, time not used as feature.
RMSE = 16935.4075



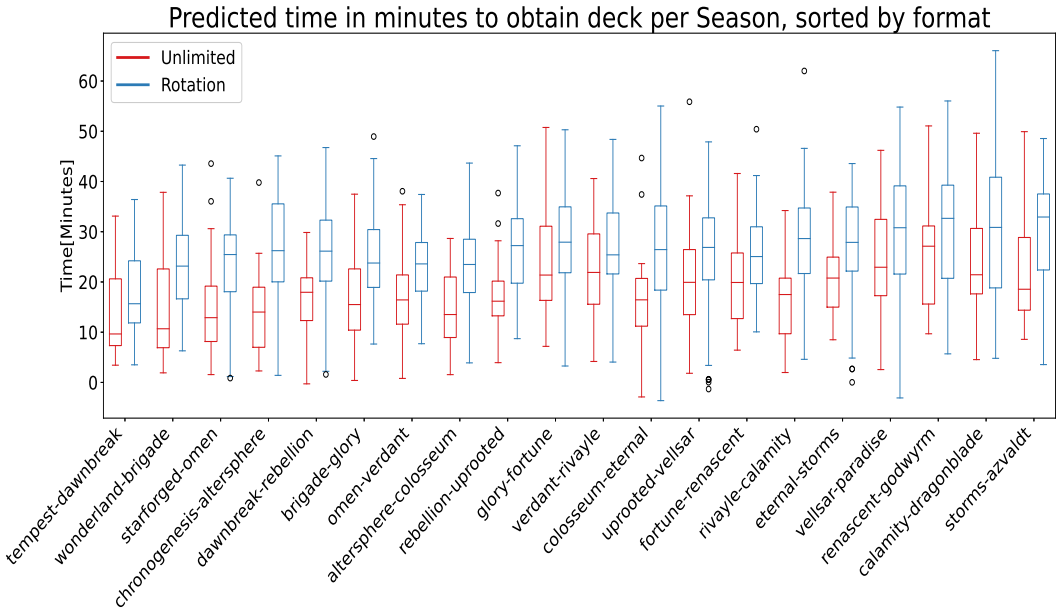
(b) Predicted time, *Vials* not used as feature.
RMSE = 11.7781

Figure 13: Predictions, quantitative variables not used.

When taking into account the fact that there are a lot of outliers, it was surprising to see that using the deck's vial cost as a feature improve the root mean square error so drastically. The interesting observations in figure 14b are that the model also predicted outliers and that the standard deviation of each box plot is much, much higher than the real data.



(a) Predicted *Vials*, time used as a feature.
RMSE = 6160.4321



(b) Predicted time, *Vials* used as a feature.
RMSE = 4.3199

Figure 14: Predictions, quantitative variables used.

The lowest root mean square error predictor was run by using the true time in minutes as the target as seen in table 5, using each available categorical variable and using the amount of *Vials* as a quantitative variable. As mentioned in table 3, there was a two-fold cross validation to reduce the phenomenon of over-training.

Features / Target Variable	Vials	Time in minutes
Season, Format, Craft, Use of Temporary deck	16935.4075	11.7781
Season, Format, Craft, Use of Temporary deck, Vials	N/A	4.3199
Season, Format, Craft, Use of Temporary deck, Time in minutes	6160.4321	N/A

Table 5: Performance of linear regression in root mean square error.

The performance increase, compared to the run that did not use the amount of *Vials* as a feature as seen in figure 13b, could be attributed to the fact that the predictor that did not use *Vials* as a feature was unable to account better for the outliers without the context of the real deck cost being taken into account. Comparing this to how the predictor behaved in figure 13a with using time as a feature in figure 14a, the root mean square error did improve significantly as well, but it is still very high to consider it a successful prediction.

4.4.3 Regression formula

This section of the paper is to explain, interpret and observe the weights, coefficients and results of the regression training.

To explain all of the given features, weights and differences, the data table 6 found in appendix A, will give an interpretation of each of the possible features. On the left axis is the features and on the top axis the target and whether the target used the other target as a feature. When the value is listed as 0.0, the real value is a 0. Importantly, is the fact that the daily tasks that reward rupies never needed to be contributed in the overall time to obtain one deck. Therefore, the feature that is the number of days is always 0.

4.4.4 Interpretation weights and coefficients

First off, an interpretation of the trained regression function. As seen in the table 2, the lowest root mean square error is achieved using the most-right column in table 6. With that said, the amount of *Vials* contribute with only a very small margin per vial, but, considering the average amount of *Vials* is about 45733, this would add about $45733 * 0.0006468 = 29.5201$ minutes of game time as a start on average.

The deck being a *Rotation Format* deck, generally, will increase the time to obtain the deck. However, if the deck is an *Unlimited Format* deck, generally, the total time will decrease instead. If the use of a *Temporary deck* is possible, it decreases the time needed to obtain the deck. This makes sense, as the player will already have some of the cards they need to obtain a playable deck.

For each of the different *Crafts* a different feature is also included. The interpretation of each respective *Craft* may not be accurate, as the trend line for the previous predictors completely changes in the most-right column, even though the RMSE is lowest for the most-right column. For each feature here, a positive number is the deck being more expensive and a negative number means the deck is cheaper.

Hilariously enough, the *Swordcraft Craft* is by-and-large the most expensive *Craft* out of all of the *Crafts*. Though, hilariously in-game, players refer to this *Craft* by the nickname 'Wallet Sword' for its ludicrous cost and the deck rarely performing well in tournaments.

5 Discussion

As a status update, as of the writing of this current thesis, the rewards have changed during the anniversary event specifically.

To start off, the change is most positive to the total vial cost in the *Rotation Format*. Most importantly, the amount of *Temporary deck* tickets has increased from 1 to 3 and there is an extra free 10 tickets on the latest *Expansion*, where all of the cards pulled are from one *Craft*.

Next to that, each *Craft* has been given a deck, compared to other *Expansions* where only half the *Crafts* are given a deck. Whether this is a one-time anniversary specific event or whether this is the norm going forward is not known, but it can be speculated to significantly decrease the average cost of the decks in the latest *Season*, storms-azvaldt.

A possible explanation on why the *Unlimited Format* has a big increase in the *Vials* to make a deck, as was seen in figure 8, is that decks will have to periodically be updated when a new *Expansion* releases, as in the case for the *Unlimited Format*, the decks need to be updated to face the newest cards released or in the case of the *Rotation Format*, the legal card pool gets changed entirely and the player is forced to swap cards from the oldest *Expansion* that just rotated out. When the card pool was much smaller, the impact of newer cards generally has a much bigger impact. This impact decreases somewhat as more and more *Expansions* are released.

An important fact, is that this study aims for a rough estimate to get a consumer-perspective in order to get a simpler understanding of what activities a player would spend their time in-game on. This is not complete with one game, as the best way to make use of the times in this study would be to apply this methodology, or similar in mindset with a different methodology, to get a better grasp on what activities other games would offer compared to Shadowverse, in this specific instance.

5.1 Limitations

Of course, lacking in the study is the fact that the data set can still be much more extensive and that factors, such as launch date, whether the deck contains cards from the mini-*Expansion* and date stamp of mini-*Expansions*, are not included in this research as features. As there was not enough time to include these factors whilst making the data set.

Next to that, there still is a lack of precision in the timed data. The assumption that the sample size is representative in the population makes sense from a study perspective, but this study does not have enough resources to affirm this statement on its accuracy. Contributing as well is the lack of game play footage and not being able to read/write Japanese.

Apart from the lack of data that is available online, it would also be very beneficial to get the exact win-rates for each deck and each *Craft* for each *Season* to see which decks are more effective time-wise. This would also give a cost versus performance measurement per deck, *Craft* and *Season*, which would give an important metric on the question of what deck is better for the consumer on a daily-performance basis.

5.1.1 Real-life considerations

Overall, when interpreting the results, the time it takes, before a skilled player that plays Shadowverse is able to have one deck capable of reaching the highest rank on the *Ladder*, is on average about 24.5 minutes when using the quickest methods available as viewed in figure 11. In real life, there will be a lot of variances by the following factors:

1. The reading and interpretation speed of the reader.
2. The experience of the player in deck-building in CCG's.
3. The experience of the player in card-game mechanics.
4. If the player skips any part of the story line.
5. If the player has read a guide.
6. If the player is familiar with similar multi-currency models.
7. What *Craft* the player picks as their first deck.
8. What archetype the player picks as their first deck.

In general, the more experienced the player is, the less time it will take for the player to interpret and understand the card text, in-game mechanics and the multi-currency model. Generally, the more aggressive the deck is, the cheaper the deck is to create in the first place. As the deck will consist of cheaper cards to facilitate the early game.

Even then, if the player's highly inexperienced and makes sub-optimal decisions, a deck should be accessible within a day of playing the game, which is more than practical for most player to start climbing the *Ladder*.

5.2 Further research

Due to the limited scope of a Bachelors thesis and the limitations that exist in this thesis, a bunch of proposals for future papers are proposed. These scope from extending an existing complicated problem to extending the currently available analysis.

5.2.1 Profitability of non-functional items

Due to the rise of non-functional items, as cited in *Computers in Human Behavior*[MGC+19] and in the *International Journal of Information Management*[WLL22], that are prevalent in a lot of free-to-play games these days, a study could be conducted to see how profitable the addition of non-functional item to games would be compared to traditionally only selling functional items. This would have to be a game that did not have non-functional items and, at some point and time, introduced these into the game's shop. Or could be two games that are functionally the same game, but with one game lacking either functional or non-functional items.

5.2.2 Extending the current analysis

As a further research topic, the tournament *Format* requires three decks from three different *Crafts* in order for a player to compete. With that, it means that the analysis can be extended to three decks instead of just one. This is not relevant to the current research question, as this research is for the average consumer and not an e-sports player. Therefore, a research paper that would analyse the time-invested viability of an e-sports player with this game could be a further research topic.

Next to being interesting for e-sports, it would also be a great insight for consumers in case the player wants a second deck to play with. This creates an incentive to perhaps create an environment where a player would pay to get more variety in their game play. This phenomenon exists in many more games, such as with so-called 'Massive-Multiplayer Online Role-Playing Games', where the player has a limited number of characters and can purchase more character slots. The problem that will likely arise with building more than one deck, is that the methods that are the quickest in tables 9 and 10 are finite. This would likely mean that getting enough *Vials* to build the second and third decks will take much longer.

5.2.3 Extended coupon collector's problem with limited draws

1 As mentioned earlier in chapter 2.2.2, the extension of the coupon collector's problem to include partial completeness from a number of draws with different probabilities for each coupon would give insight into the gaming industries many ways to randomize rewards, including and not limited to so called loot boxes or crates[ZMC+20], random drops[Cal21] and randomized encounter rates of monsters or other such examples for these drops. This would then give insight into how far a player would be in having parts of a complete set and whether the player should pivot to a different set, given their currently drawn coupons.

This would be an extensive research in how each of these elements would change the result set from the original problem. Preferably, also how different coupon odds influence the result and how to replicate this in other scenarios. This is all with a goal to show the consumer the dark game design patterns such as 'grinding'[ZBL13] in order to obtain these resources and, as an extension, how multiple games with different probabilities have an influence in the total amount of drops necessary to obtain all of the items in the listed pool.

5.2.4 The physical trading card game

The physical card game has also been released during the writing of this thesis. The comparison would not be able to be made in just in-game time as there is an actually cost in money for real cards, but would likely focus more on the sustainability of decks by counting the amount of wins, the cards listed in the deck and the date that the deck won. Such a study would be able to analyse the longevity of all the existing decks in the current market space. Most importantly, how expensive the card game would be, when a player keeps up with the best decks. Next to that, there is a possibility that each individual card can be weighted by the amount of wins the card has achieved, making a performance metric per card. This is a phenomenon called a 'staple' when it comes to cards and staples generally create the backbone of building a competitive deck[Bay21].

5.2.5 Magic circle with monetization models

The influence of changes in the current monetization model is not very well known when it comes to the lengths a player would be willing to go to in order to achieve a goal that is achievable in-game. The problem arises when the player's immersion is broken by a way that the player is not able to stay within the Magic Circle, as an example given; a mandatory purchase in order to complete a certain goal. This, in term, has created an environment where companies have made grave mistakes with their player population, where the company has overestimated their ability to monetize a game. An infamous example of this, is the Electronic Arts community manager quote that is the most down-voted post on the popular social media platform Reddit:

> "The intent is to provide players with a sense of pride and accomplishment for unlocking different heroes."

This was in response to a user asking why someone would have to pay eighty US dollars to unlock the popular Star Wars character Darth Vader in the game Star Wars Battlefront (2015).

Whilst this may sound egregious, the same amount of money would roughly get a player one high rarity character in the popular mobile game Genshin Impact. This, however, is not met with the same amount of outrage and discontent that the first scenario provided, despite the end goal being exactly the same: unlocking a playable character that was not available before this purchase.

There are many cases of this where there is not enough knowledge on how to test a monetization model such that the player will not be outraged or, in similar fashion, is encouraged to actively protest against the game.

5.2.6 Generic methodology

For further research using the same method as described in this research the following notes have to be taken into consideration:

- Final states of the account must be defined before starting this analysis.
  This means that a list of sets of all of the objects that are necessary (and all optional objects that the user may have) are defined at the start of the research and all the ways to obtain such objects are included in the feature weights, noting all exceptions that have taken place.

- Each way of obtaining the required objects from their respective currencies has to be sorted in the most-to-least effective minutes spend to obtain the amount of currency required.
  This is to only use effective transactions, such that this will save in-game time.

- The methods of obtaining currencies are documented into two types of features:

  - The currency is obtainable without an in-game timer stopping the player from obtaining the currency.
  - The currency has a timer and this method adds a feature that is how many times this method is used to calculate the amount of timer periods the user has to sit through. This feature is a tuple with the encoded feature that this method represents.

This is such that there is an insight in the overall amount of effort the user has to do to integrate the game into their life's' daily structure in order to obtain the necessary materials with the least time spend in the game itself. This is mostly seen in the type of task that has to be completed daily for a set of rewards.

- Each in-game activity is sorted from most to least effective way to obtain the currency and is noted by the maximum amount of currency that in-game activity generates per completion.
  This is done by measuring the in-game time for completing a method to obtain currency and then dividing the amount of currency by the time it takes to get that amount. This then gives back a performance metric of currency per minute of time.

- For regression, the formula weights and coefficients have to be reported to explain which features have had the biggest influence. For classification, which features are most significant in the ROC space [Faw06].
  This is such that all of the comparisons are consistent and transparent.

- For each of the features that make them distinct from each other when training the target feature, plot a graph such that the difference in the target feature is clearly shown.
  This is to see how much of a difference the feature actually makes when the feature is suspected to be a major difference in the data set.

6 Conclusion

As an observational study, the time it takes to finish a deck is on average 24.5470 minutes. The time to obtain any deck is at least 5 and at most 86 when using the quickest methods available in-game to satisfy the requirements to create the deck. The time it takes to achieve the Grand-Master rank is estimated to be roughly 13467.03125 minutes, with the assertion that a skilled enough player achieves an at least 50% win rate. All other *Game modes* are already accessible in about 5 minutes of in-game time, this being the time to finish the tutorial.

As a consequence, the total amount of time that is actually spend to obtaining a deck for the *Ranked mode Game mode*, as shown in figure 11 , and when assuming a user is of the *Grand Master Rank* and has one deck, is only 0.18% of the total time that it takes to obtain one deck. The other *Game modes* in Shadowverse are accessible after the tutorial, which takes about 5 minutes.

This means that the methodology described in chapter 4.2 will be able to give a rough estimate on the in-game time in order to be able to participate properly in each possible activity in the game of Shadowverse. In term, it means that this analysis will be able to be run on similar games, by extension, creating a meaningful comparison between games that the average consumer can understand before playing the game by using similar methodology described in chapter 5.2.6. The consumer will be able to see what a game offers before the consumer has to spend a substantial amount of time finding out what a game's activities are, how the currency spending model works and the best way to spend that currency. In the end, the decision whether the activities fit with the consumer's wants and needs given the time-investment can be made **before** playing the game this way.

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A Regression formula coefficients and weights

Feature	Variable	Vials, no time	Vials, used time	Time, no Vials	Time, used Vials
Vials or Time feature	Time on vial, vial on time	N/A	1316.1796	N/A	0.0006468
Format	Rotation	6128.3642	698.7818	3.9259	0.0929
	Unlimited	-6128.3642	-698.7818	-3.9259	-0.0929
Used temp deck	true	-8757.8221	-1083.6209	-5.9163	-0.1641
	false	8757.8221	1083.6209	5.9163	0.1641
Craft	forest	-14.0197	-866.4289	0.1234	0.5932
	sword	8719.9339	1427.7289	4.3508	0.0814
	rune	-11539.7318	-2014.8225	-7.8165	0.2247
	dragon	3984.9360	829.1459	2.9219	-0.175
	shadow	2466.5035	1089.0712	0.7382	-1.0379
	blood	-2825.1127	-1328.1757	-1.5022	0.1816
	haven	-2513.1289	-21.1180	-0.2348	0.4976
	portal	1720.6196	884.5990	1.4190	-0.3652
Season	tempest-dawnbreak	0.0	-131.2477	0.0	-0.8320
	wonderland-brigade	0.0	-255.2639	0.0	-0.7156
	starforged-omen	0.0	-592.8258	0.0	-0.3250
	chronogenesis-altersphere	-3722.2995	0.0	-2.6357	0.0
	dawnbreak-rebellion	-4953.5871	0.0	-3.5682	0.0
	brigade-glory	-4002.5382	0.0	-2.6513	0.0
	omen-verdant	-8186.8687	-2939.1504	-5.8775	0.8134
	altersphere-colosseum	-7355.1697	0.0	-4.6839	0.0
	rebellion-uprooted	0.0	-1045.8234	0.0	0.5743
	glory-fortune	2043.3921	0.0	1.2619	0.0
	verdant-rivayle	0.0	-192.6092	0.0	0.2475
	colosseum-eternal	5937.8980	0.0	4.4564	0.0
	uprooted-vellsar	0.0	276.6445	0.0	0.1650
	fortune-renascent	3526.1430	0.0	2.4906	0.0
	rivayle-calamity	0.0	595.3972	0.0	-0.0481
	eternal-storms	4945.9996	0.0	2.6615	0.0
	vellsar-paradise	0.0	699.0283	0.0	0.2687
	renascent-godwyrm	0.0	1711.3203	0.0	0.006090
	calamity-dragonblade	11767.0305	0.0	8.5463	0.0
	storms-azvaldt	0.0	1874.5301	0.0	-0.1542

Table 6: Feature weights and their coefficients.

B Data source tables

Ranked match Time[Minutes]	Source Ranked match
13.11666667	https://www.youtube.com/watch?v=Hku3Yim327s
9.583333333	https://www.youtube.com/watch?v=Hku3Yim327s
12.81666667	https://www.youtube.com/watch?v=Hku3Yim327s
9.366666667	https://www.youtube.com/watch?v=Hku3Yim327s
15.71666667	https://www.youtube.com/watch?v=Hku3Yim327s
10.38333333	https://www.youtube.com/watch?v=Hku3Yim327s
14.35	https://www.youtube.com/watch?v=Hku3Yim327s
4.916666667	https://www.youtube.com/watch?v=Hku3Yim327s
21.33333333	https://www.youtube.com/watch?v=Hku3Yim327s
13.25	https://www.youtube.com/watch?v=Hku3Yim327s
13.1	https://www.youtube.com/watch?v=Hku3Yim327s
13.63333333	https://www.youtube.com/watch?v=Hku3Yim327s
11.46666667	https://www.youtube.com/watch?v=Hku3Yim327s
12.15	https://www.youtube.com/watch?v=Hku3Yim327s
5.383333333	https://www.youtube.com/watch?v=Hku3Yim327s
15.46666667	https://www.youtube.com/watch?v=Hku3Yim327s
16.95	https://www.youtube.com/watch?v=Hku3Yim327s
13.33333333	https://www.youtube.com/watch?v=Hku3Yim327s
7.833333333	https://www.youtube.com/watch?v=Hku3Yim327s
17.65	https://www.youtube.com/watch?v=Hku3Yim327s
16.76666667	https://www.youtube.com/watch?v=Hku3Yim327s
15.05	https://www.youtube.com/watch?v=Hku3Yim327s
6.933333333	https://www.youtube.com/watch?v=Hku3Yim327s
10.61666667	https://www.youtube.com/watch?v=Hku3Yim327s
11.71666667	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
7.65	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
7.4	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
14.45	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
17.93333333	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
9.733333333	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
12.05	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
14.01666667	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
9.35	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
13.96666667	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
15.96666667	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
14.38333333	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
5.283333333	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
11.81666667	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
10.71666667	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
12.45	https://www.youtube.com/watch?v=zqXBwOSZ5OQ

10.75	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
9.933333333	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
12.5	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
13.05	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
11.46666667	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
12.1	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
13.75	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
11.58333333	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
14.68333333	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
15.93333333	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
17.03333333	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
13.35	https://www.youtube.com/watch?v=zqXBwOSZ5OQ
14.13333333	https://www.youtube.com/watch?v=zqXBwOSZ5OQ

Table 7: Time data points measured with source *Ranked mode Game mode*

Story match	Source Story match YouTube playlist hash youtube.com/playlist?list={hash}	Chapter	Craft	Story chapter
5.7	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	13	sword	1
5.3333	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	14	sword	1
4.2	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	12	dragon	1
2.93333	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	12	rune	1
4.8667	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	14	rune	1
5.6667	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	14	dragon	1
9	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	14	forest	1
2.93333	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	11	forest	1
5.9833	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	12	forest	1
7.35	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	13	forest	1
7.4833	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	13	shadow	1
9.9667	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	14	shadow	1
4.15	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	13	blood	1
4.1833	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	13	blood	1
6.7833	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	14	blood	1
4.75	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	13	haven	1
5.0167	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	14	haven	1
4.5	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	2	any	2
5.1667	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	3	any	2
5.6667	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	4	any	2
6.55	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	5	any	2
3.65	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	6	any	2
11.267	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	7	any	2
5.73333	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	8	any	2
6.83333	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	9	any	2
4.03333	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	10	any	2

9.3333	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	11	any	2
3.1667	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	4	portal	1
3.93333	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	5	portal	1
9.3667	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	6	portal	1
13.617	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	14	any	4
4.4167	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	5	haven	7
6.05	PLyO1YFAzrh3mIiRIeaVUqK4p-0zPFrShT	1	shadow	1
3	PLyO1YFAzrh3mIiRIeaVUqK4p-0zPFrShT	2	shadow	1
3.13333	PLyO1YFAzrh3mIiRIeaVUqK4p-0zPFrShT	3	shadow	1
3.03333	PLyO1YFAzrh3mIiRIeaVUqK4p-0zPFrShT	9	sword	1
6.05	PLyO1YFAzrh3mIiRIeaVUqK4p-0zPFrShT	10	word	1
3.63333	PLyO1YFAzrh3mIiRIeaVUqK4p-0zPFrShT	11	sword	1
8.05	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	4	any	3
8.3667	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	13	any	4
12.867	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	15	any	4
8.73333	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	6	any	6
6.9	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	7	any	6
6.3	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	8	any	6
6.3667	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	5	any	8
10.4833	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	14	any	8
6.63333	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	7	any	9
8.73333	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	12	any	9
11.817	PLDt7AIXM7PBnFFLBxDel3AQeDv0svnmAV	12	any	9
5.55	PLyO1YFAzrh3mIiRIeaVUqK4p-0zPFrShT	13	any	4
4.1667	PLyO1YFAzrh3mIiRIeaVUqK4p-0zPFrShT	15	any	4
8.4167	PLLtleBc-0yyFv1Sw9pr3I80o1xaK7LvG9	13	any	4
6.8167	PLLtleBc-0yyFv1Sw9pr3I80o1xaK7LvG9	15	any	4
11.7833	PLLtleBc-0yyFv1Sw9pr3I80o1xaK7LvG9	6	any	6
8.95	PLLtleBc-0yyFv1Sw9pr3I80o1xaK7LvG9	7	any	6
7.55	PLLtleBc-0yyFv1Sw9pr3I80o1xaK7LvG9	8	any	6
9.63333	PLLtleBc-0yyFv1Sw9pr3I80o1xaK7LvG9	14	any	8
10.0833	PLLtleBc-0yyFv1Sw9pr3I80o1xaK7LvG9	7	any	9
13.6833	PLLtleBc-0yyFv1Sw9pr3I80o1xaK7LvG9	12	any	9
7.8833	PLLtleBc-0yyFv1Sw9pr3I80o1xaK7LvG9	12	any	9

Table 8: Time data points measured with source *Story mode Game mode*

The tables 9 and 10 are assigned an ID such to fit the full methods table.

ID	Challenge Tickets	Vials	Rupies	Game mode	Game action	Repeats	Match time [Minutes]	Total match time [Minutes]	Time [Minutes]
0	3.0	400.0	5600.0	starting	complete tutorial and claim rewards	1	5.0	5.0	20
1	0.0	0.0	300.0	mission	link shadowverse account	1	0.0	0.0	5
2	0.0	0.0	100.0	mission	edit a deck and change a card	1	0.0	0.0	2
3	0.0	0.0	100.0	achievement	private match	20	1.0	20.0	3
4	0.0	0.0	200.0	achievement	ai match elite	25	2.0	50.0	10
5	0.0	0.0	600.0	story mode	the empyrean inn last resort	1	8.0	8.0	40
6	0.0	0.0	500.0	story mode	fate's trigger conclusion	1	8.0	8.0	40
7	0.0	0.0	650.0	story mode	entropy abyss reconclusion	1	12.0	12.0	60
8	0.0	0.0	300.0	story mode	entropy abyss	4	6.0	24.0	30
9	0.0	0.0	300.0	story mode	fate's trigger	4	6.0	24.0	30
10	0.0	0.0	300.0	story mode	the empyrean inn	3	6.0	18.0	30
11	0.0	0.0	690.0	story mode	the final loop	1	14.0	14.0	70
12	0.0	0.0	420.0	story mode	Gears of rebellion uprising	1	10.0	10.0	50
13	0.0	0.0	450.0	story mode	seeds of conflict harrowing	1	12.0	12.0	60
14	0.0	0.0	150.0	battle pass mission	play 5 games of take 2	1	5.0	5.0	15
15	0.0	0.0	390.0	story mode	invasion of the worldreaver	1	12.0	12.0	60
16	2.0	100.0	400.0	story mode	the morning star	7	16.0	112.0	75
17	0.0	0.0	280.0	story mode	guild wars(12 chapter)	4	10.0	40.0	50
18	0.0	0.0	350.0	story mode	seeds of conflict	4	14.0	56.0	70
19	0.0	0.0	50.0	achievement	play 1 take two match	1	1.0	1.0	10
20	2.0	100.0	100.0	story mode	morning star conclusion	1	22.0	22.0	110

21	0.0	0.0	100.0	mission	win 1 ranked match	1	2.0	2.0	24
22	0.0	0.0	400.0	story mode	guid wars conclusion	1	20.0	20.0	100
23	0.0	0.0	280.0	story mode	gears of rebellion	4	14.0	56.0	70
24	0.0	0.0	260.0	story mode	guild wars(13 chapter)	4	14.0	56.0	70
25	0.0	0.0	50.0	battle pass mission	play 5 games of open 6	1	5.0	5.0	15
26	0.0	300.0	0.0	temp gem mission	win 3 ranked matches	1	6.0	6.0	72
27	0.0	0.0	100.0	achievement	achieve beginner rank 3	1	12.5	12.5	150
28	0.0	0.0	20.0	achievement	reach level 10 in craft	8	10.0	80.0	30
29	0.0	0.0	35.0	daily missions	complete missions	3	2.0	6.0	60
30	0.0	0.0	30.0	achievement	reach level 15 in craft	8	20.0	160.0	60
31	0.0	0.0	30.0	achievement	reach level 20 in forestcraft	1	20.0	20.0	60
32	0.0	20.0	20.0	story mode	the morning star yuwan	1	6.0	6.0	60
33	0.0	0.0	52.5	daily missions (old)	complete missions	3	12.5	37.5	125
34	0.0	0.0	20.0	achievement	win ranked match in craft 5 times	8	10.0	80.0	240

Table 9: Methods to obtain *Vials*, sorted by most efficient method on top part 1.

ID	Rupies/minute	Vials/minute	Total possible rupies	Amount of Card pack tickets	Amount of total Vials	Total Vials/minute
0	880.000000	20.000000	6200.0	62.000	29602.0	1500.1
1	60.000000	0.000000	300.0	3.000	1413.0	282.6
2	50.000000	0.000000	100.0	1.000	471.0	235.5
3	33.333333	0.000000	2000.0	20.000	9420.0	157.0
4	20.000000	0.000000	5000.0	50.000	23550.0	94.2
5	15.000000	0.000000	600.0	6.000	2826.0	70.7
6	12.500000	0.000000	500.0	5.000	2355.0	58.9
7	10.833333	0.000000	650.0	6.500	3061.5	51.0
8	10.000000	0.000000	1200.0	12.000	5652.0	47.1
9	10.000000	0.000000	1200.0	12.000	5652.0	47.1
10	10.000000	0.000000	900.0	9.000	4239.0	47.1
11	9.857143	0.000000	690.0	6.900	3249.9	46.4
12	8.400000	0.000000	420.0	4.200	1978.2	39.6
13	7.500000	0.000000	450.0	4.500	2119.5	35.3
14	10.000000	0.000000	150.0	1.500	706.5	47.1
15	6.500000	0.000000	390.0	3.900	1836.9	30.6
16	405.333333	1.333333	3200.0	32.000	15172.0	30.2
17	5.600000	0.000000	1120.0	11.200	5275.2	26.4
18	5.000000	0.000000	1400.0	14.000	6594.0	23.6
19	5.000000	0.000000	50.0	0.500	235.5	23.6
20	400.909091	0.909091	500.0	5.000	2455.0	23.2
21	4.166667	0.000000	100.0	1.000	471.0	19.6
22	4.000000	0.000000	400.0	4.000	1884.0	18.8
23	4.000000	0.000000	1120.0	11.200	5275.2	18.8
24	3.714286	0.000000	1040.0	10.400	4898.4	17.5
25	3.333333	0.000000	50.0	0.500	235.5	15.7
26	0.000000	4.166667	0.0	0.000	300.0	8.3
27	0.666667	0.000000	100.0	1.000	471.0	3.1
28	0.666667	0.000000	160.0	1.600	753.6	3.1
29	0.583333	0.000000	105.0	1.050	494.6	2.7
30	0.500000	0.000000	240.0	2.400	1130.4	2.4
31	0.500000	0.000000	30.0	0.300	141.3	2.4
32	0.333333	0.333333	20.0	0.200	114.2	2.2
33	0.420000	0.000000	157.5	1.575	741.8	2.0
34	0.083333	0.000000	160.0	1.600	753.6	0.4

Table 10: Methods to obtain *Vials*, sorted by most efficient method on top part 2.