Game Utility Metrics And The Prospects of Cloud Gaming

Albert Rafetseder[1], Florian Metzger[2], and Svenja Schröder[3]

[1] NYU Tandon School Of Engineering, USA
albert.rafetseder@univie.ac.at
[2] Chair of Modeling of Adaptive Systems
University of Duisburg-Essen, Germany
florian.metzger@uni-due.de
[3] Universität Wien, Austria
svenja.schroeder@univie.ac.at

Abstract In recent years, cloud gaming has become a popular research topic, and the list of its supposed benefits is long. However, cloud gaming platforms are still waiting for the commercial breakthrough. This might be caused by the pricing models and product offerings by existing "à la carte" platforms. This paper investigates the costs and benefits of both platform types. Based on a multi-platform dataset that spans the last two years, utility metrics for the platforms are discussed. A cost utility model is then developed to make the different pricing policies comparable. The analyses presented provide an initial, yet still comprehensive insight for the prospects of cloud gaming in a highly competitive market.

1 Introduction

Cloud gaming has become quite a popular research topic in recent years. Much of this research is aimed at comparing the experienced quality of cloud gaming to that of conventional gaming approaches, often with reasonable results for the streaming approach (cf., for example, [1]). So, if there are only negligible quality drawbacks, what about the commercial success of cloud gaming? Intuitively, one would assume that this could yield substantial benefits in terms of cost and flexibility as a result of scaling effects through the used cloud gaming hardware in comparison to equipment-heavy classical home gaming approaches. However, the cloud gaming market seems to stagnate with a high rate of fluctuation, i.e., a constant stream of market entrances and exits. For example, one of the most prominent services in the past, OnLive, ceased to exist in 2015.

Cloud gaming platforms have tested many different technical, service and pricing models already. They currently adopt either Netflix-like pure subscription models, surcharge for additional games, or employ usage-based billing. Regardless, the public interest remains low. This might be attributed to the broad range of available, established substitutes, e.g., non-cloud gaming platforms such as video game consoles or PCs — with Steam[4] as one of the largest contenders.

[4] http://store.steampowered.com/

The move to digital distribution made gaming on PCs quite popular, and PC games pricing became much more dynamic and affordable in the process. Additionally, their offer is much larger and more diverse.

The research question explored in this work considers the utility offered to customers by current cloud gaming platforms, as compared to gaming platforms for the PC. Various utility metrics such as the number of offered games, playthrough lengths, review scores, and prices are investigated. The evaluation is based on combining and investigating large datasets of user choice and game properties. Finally, a model is proposed that expresses customer utility in different gaming platforms as a function of cost. These results provide data-driven insight into potential causes for and against cloud gaming.

This paper is structured as follows: § 2 provides a brief overview of the related work. § 3 explains the technical background, ecosystems, and utility metrics. §§ 4 and 5 investigate the utility of (cloud) gaming providers' service offerings and business cases, and present a cost utility model for comparing the offers. The analysis is based on a dataset spanning more than two years and multiple platforms. The paper concludes in § 6 with directions for future work.

2 Related Work

Unfortunately, we are not aware of publications that treat utility aspects of gaming or cloud gaming offers specifically. However, aspects focusing on gameplay have been scrutinized in the literature, in particular regarding network Quality of Service (QoS) and user Quality of Experience (QoE). This section revisits material that reflects the users' quality expectations when playing computer games.

The quality of games is revisited along the axes of end-to-end (E2E) lag, image quality, and frame rates. Considerable research efforts have been put into the network delay component of the E2E lag for both online games and cloud gaming. The results, however, remain inconclusive. Studies of multiplayer games often focused on First-Person Shooters (FPSs) such as *Quake 3* [2] or *Unreal Tournament 2003* [3]. Concerning cloud gaming, Chen et al. [4] for example find very high and variable delay values even when neglecting the network delay. Furthermore, [5] gives some insights on the delay requirements of streamed games and the implications for data center distance as well as placement.

Image quality represents a further QoE factor. Gaming adds another dimension to typical image quality assessments, as most games allow for changes to their graphical fidelity, be it either the resolution or more demanding graphical features, such as ambient occlusion or anti-aliasing. Cloud gaming usually locks these options at one specific setting for a specific quality-to-resource-demand trade-off, resulting in an often lower source quality than what local games can offer. As an example, the work in [6] takes a look at different encoding parameters for cloud gaming.

Finally, and often neglected, is the game's frame rate and the streaming frame rate. Due to the interactivity of the media the requirements are generally higher than for video streaming, e.g., 60 Hz is an accepted standard for many games. Too low frame rates will result in a reduced quality due to observable stuttering and issues with inputting commands. An overview of some further QoE taxonomy and influence factors especially for mobile games is given in [7]. Several efforts also set up subjective tests of cloud gaming services with specific QoS parameters in mind. Such studies can be found in, e.g., [8] and [9]. Efforts have also been made towards an ITU-T recommendation for subjective game testing as reported in [10].

3 Background

This section reviews some terminology used in this paper, presents the current hardware and software platforms and ecosystems for different types of gaming, introduces utility metrics for games, and describes the data sources used for the evaluations in this paper. All costs are from an European, specifically German, perspective. If a product is not available in this region, the prices are converted using the most recent currency exchange rates.

A game application collects user input, manages local game state, possibly synchronizes with remote entities, and renders audio and video contents in response. In the simplest case, these tasks all run collocated on the gamer's local machine. In cloud gaming, games are executed and rendered "in the cloud" (i.e., in remote data centers), and an audio/video stream is sent back to the player over the network. The user's local gaming device displays the stream, records input and sends it back to the remote side for processing. Video decoding is less computationally demanding than rendering a game, so the local device need not be as powerful. However, requirements are higher for the network connecting the cloud and the local device.

There are two approaches to cloud gaming on the market currently that differ in who provides the actual game applications that can be executed in the cloud. One, the provider chooses, installs, configures, and updates the game applications. This is termed Gaming as a Service (GaaS) in this paper. In the other approach, the gamer leases a virtual machine from the provider, but must supply own games. The provider takes care of provisioning sufficient resources so that games can be run. This is termed cloud rendering here.

3.1 Gaming Hardware

Gaming PCs Hardware viable for PC gaming starts at about €500 but has practically no upper limit for enthusiasts. The Graphics Processing Unit (GPU) is a cost driver, and it is essential for modern PC gaming. This poses a certain financial barrier for customers to start PC gaming, which is however compensated by an increased flexibility and longevity of hardware.

Video Game Consoles Dedicated consoles represent the classical approach to video gaming. The price for (non-portable) consoles varies but usually lies

Table 1. Content and price models of cloud gaming services and selected digital distribution platforms. Services are described from the EU/Germany region unless stated otherwise.

Service	Model	Hardware	Monthly Subscription Fee	Usage-based cost	No. of Titles	Regional Restrictions	Notes
GeForce NOW	GaaS	SHIELD device	€9.99	None	55 included, 63 surcharge	North America, Europe, Japan	
GeForce NOW for PC	cloud rendering	PC	None	$25 for 10 h to 20 h, quality dependent	n/a	North America	currently in free beta, prices based on latest announcement[a]
PlayStation Now	GaaS	PS3/4 consoles	€16.99	None	432	12.26 h	selected PS3/PS4 games
PlayStation Now on PC	GaaS	PC	— *(otherwise identical with* PlayStation Now*)* —				
LiquidSky	cloud rendering	PC or smartphone	$19.99	for usage exceeding 80 h	n/a	North America, Europe, Hong Kong	Limited storage
GameFly	?	?	?	?	?	?	Only for specific set-top boxes
Steam	direct game sales	PC	None	None	14,120	pricing and availability of games differ across regions	

Defunct Services	Model	Notes
OnLive	GaaS	Bankrupt, most patents sold to Sony (2015)
Gaikai	GaaS in web browser	Bought by Sony (2012)[b]
Gface (CryTek)	unknown	Did not leave beta (2012), now just a company game launcher (also defunct)
Playcast	unknown	50 games, selected ISPs,only for specific set-top boxes. Merged with GameFly (2015)

between €300 and €400 for the latest console generation, i.e., *Switch*, *PlayStation 4*, and *Xbox One*. While priced lower than PCs, console hardware is not componentized and not upgradeable as easily.

Cloud Gaming Hardware One of the main claimed benefits of cloud gaming is its low requirements on end user hardware. Thus, a less powerful PC may suffice to use a cloud gaming service as long as the network connection to the service provides an adequate latency and bandwidth. Sony's PlayStation Now cloud gaming service was originally available only for their PlayStation 3 and 4 consoles, and a line of their TV sets. The latter option has since been removed, and streaming to PCs enabled instead.

Companies also experiment with devices that focus exclusively on streaming cloud gaming content. The most recent standalone game streaming device currently in the market is NVIDIA's *SHIELD* which starts at €230 and is bound to their cloud gaming service, GeForce NOW. Here, too, a stream-to-PC option has become available recently (as a US-only beta programme).

3.2 Gaming Ecosystems

Below, currently active (cloud and non-cloud) gaming platforms are examined with regards to pricing models, other requirements, and costs. The information presented was collected between July 2015 and October 2017. Table 1 overviews these platforms, and also mentions some that shut down in the timeframe.

PC Gaming The rise of easy-to-use digital distribution platforms and the independent ("indie") game scene reinvigorated PC gaming just a few years ago. Today, PC gaming is dominated by digital marketplaces, with Steam being the largest. The platform has about 10 million concurrent users at most times of the day. It periodically offers large, often seasonal, sales of recent games at greatly reduced prices (rebates of 75% for a year-old game are not uncommon). In addition, many resellers offer digital codes for other platforms, often at much lower prices. Major releases on PC are usually priced between €50 and €60. However, due to the competition between the vendors, the digital retail prices are significantly lower even at launch, and also drop more quickly. Another recent trend are game bundles, which especially prevail in the indie games scene, commonly offered with a pay-what-you-want model. *Humble Bundle*[5] is a prominent example.

Video Game Consoles New, major game releases are mostly priced at either €60 or €70. Once on the market, the game prices decrease rather slowly. In recent years, retail stores have been complemented with console-specific, proprietary digital distribution services that also offer the latest game at the full price.

[5] `https://www.humblebundle.com/`

These official stores are usually exclusive vendors for digital game codes where competitors are excluded.

Subscription fees often apply for the multiplayer mode of games, e.g., *PlayStation Plus* or *Xbox Live Gold* with annual prices of €50 and €60, respectively. These services also include access to a small, monthly changing palette of older titles.

Cloud gaming Ecosystems NVIDIA's cloud gaming platformGeForce NOW is available in North America and select European countries. In Germany the service currently offers 55 PC titles for a monthly subscription fee of €10. An additional per-game one-time fee is charged for the access to 63 other games. The service is delivered from six specialized data center locations (Dublin and Frankfurt in Europe).

The requirements to use this service are rather steep, demanding 50 Mbit/s for a full 1080p60 stream[6] (10 Mbit/s in order to use the service at all) and a maximum RTT of 60 ms to one of the data centers. In addition, streaming is exclusive to *SHIELD* devices.

The GeForce NOW for PC beta program streams to PCs, and costs $10 to 20 per hour of usage depending on the desired visual quality.

PlayStation Now, Sony's cloud gaming service, offers to stream titles from previous PlayStation generations, as the latest console generation lacks backwards compatibility. The service offers 432 games for a monthly flat rate of €17. This is in addition to the device cost: the service is available on PlayStation 4 and 3 consoles and, recently, PCs.

The streaming itself is performed at a resolution of 720p60[6] requiring a 5 Mbit/s connection. Reports on the video quality have been rather mixed.[7]

Like GeForce NOW for PC, LiquidSky is a cloud rendering service. Here, 80 h of gameplay are included in the €20 monthly subscription; games must be purchased separately, and a local streaming device (of any kind) is needed.

GameFly is a recent offer for set-top boxes, but little other detail is public at the time of writing.

3.3 Utility Metrics

Utility metrics help to estimate the value of a service for a customer. It should be noted that no single metric is likely of value by itself, yet all metrics somehow influence customer decisions.

The first basic metric is the number of games offered. A larger number means more choice for the customer, but "spam" phenomena need to be considered, as large offers might include many games of sub-par quality.

[6] This 60 Hz frame rate represents the rate of the video encoder. The game's actual frame rate might be considerably lower depending on the complexity of the game.

[7] `http://www.eurogamer.net/articles/digitalfoundry-2015-hands-on-with-playstation-now`

Second, the number of players already owning a game can be a motivating factor for other customers to choose the same game. One may interpret this as a form of preferential attachment. This is particularly interesting for decidedly online games, i.e. such where players interact in the game environment over the network, so that more interactions are possible if more players are online.

Then, games are priced differently, both within and across platforms. Many games are offered completely free of charge. Some are funded indirectly through in-game purchases. On the other end of the spectrum, titles whose development was expensive and for which the audience anticipation is high will probably sell for a correspondingly high price.

Furthermore, game lengths come to mind. Games range from very short (on the order of minutes) to tens of hours (for games with an extensive storyline), but need not be limited at all (e.g. explorative or "open world" games). Game length should thus be considered differently depending on the player type. For casual gamers, shorter games probably have more appeal, as their limited playtime is more likely to allow players to complete them. "Hardcore" gamers that spend more time gaming overall might find longer games more engaging. Overall, neither mode intrinsically offers higher utility.

Next, the age of games (per their original release date) is of interest. Some players favor the newest games, others prefer "classics"; any focus or combination thereof will likely attract specific proportions of customers. Also, newer games tend to also be topics in the media (and in advertising, increasing their publicity), offer a greater diversity (e.g., regarding game mechanics and control), and feature improved technical quality (resolution, scene complexity).

There also exist considerable amounts of secondary literature about games in the form of reviews. These can be viewed as social factor, in that gamers might be drawn to positively-reviewed titles more strongly, or rather stay away from less favorably reviewed ones. Some media aggregate reviews from many outlets and are thus of particular interest for an analysis.

Many other utility metrics are imaginable, e.g. the motivation to buy games for a platform that the gamer already possesses, the number of platform "exclusive" game titles, the game genre and other classifications, the number of game sales and subscriber numbers, technical aspects like graphical fidelity, performance, precision and responsiveness of controls, measures of the game's content like variety and quality of game mechanics, or other content-centric factors.

Lastly, any combination of the metrics mentioned above has its merits for assessing the utility of a gaming platform. For example, the combined expected playthrough length of the top 10% of games across platforms could be evaluated, and judged against the amount of money required to equip each platform like this.

3.4 Data Sources

In order to investigate the utility metrics described, data was collected from multiple sources and merged (with a few instances of omission and double-count) into a data base. In the interest of repeatability and reproducibility, all of the data reported on in this work, as well as the code used to collect and process it, can be found in public repositories[8]. Data were joined on game names and platforms (where appropriate). The different data sources are described in the following.

For Steam, the public REST API was used to fetch the name and current price of each game at different points in time[9]. This data was combined with API data from the 3rd-party site *SteamSpy*[10], which parses all publicly visible Steam user profiles and estimates statistics on the size of the player base and the time each player spends with a title. *SteamSpy* also provides a heuristic projection of the total number of owners of each listed title on Steam. For GeForce NOW, game names and prices were screen-scraped manually. Game names for PlayStation Now is available from the PlayStation website[11]. Through this, the portfolios can be compared between platforms.

Game publishers seldom publish intended playthrough length of games, and not all games necessarily have one. However, players may self-report their experienced playthrough times on sites like How Long To Beat[12], which was web-scraped for this analysis using a custom tool[13].

Lastly, the age of a game is computable from its release date. To this end, the Metacritic[14] page which aggregates reviews of video games (and other media) was scraped[15].

4 Evaluation

This section investigates the properties of the actual games offered on the various platforms, so as to provide a backdrop against which utility metrics can be viewed. Table 2 provides an overview of the data.

Number of Games The two cloud platforms offer a very limited number of games when compared to the games available on Steam, which itself again only represents a subset of all games available either on the PC platform (Metacritic lists 26,420) or across all platforms (57,308). Two possible, simple explanations for the low game count on the cloud platforms come to mind: One is that they were launched relatively recently (2015) in comparison to Steam (2003), leaving little time for the range of games to grow. Secondly, the choice of games for a cloud gaming platform is most likely curated by the platform operator for compatibility and performance reasons. This usability burden shifts to the end

[8] The repository resides at `https://github.com/mas-ude/cost-of-cloud-gaming`
[9] `https://github.com/mas-ude/steam-data-stats`
[10] `https://steamspy.com`
[11] `https://www.playstation.com/de-de/explore/playstation-now/ps-now-games/`
[12] `http://howlongtobeat.com/`
[13] `https://github.com/mas-ude/gamelengths-scraper`
[14] `http://www.metacritic.com/`
[15] `https://github.com/mas-ude/metacritic_scraper`

Table 2. Game characteristics on the investigated platforms. Title counts from Web/API scraping, lengths from How Long To Beat, ages and review scores from Metacritic.

Service	Titles	Age μ	Age σ	Length μ	Length σ	Score μ	Score σ
GeForce NOW	118	3.1 yrs	±2.3 yrs	10.7 h	±8.2 h	73.9	±10.1
PlayStation Now	432	4.8 yrs	±2.4 yrs	8.8 h	±8.8 h	71.9	±12.0
Steam	14,120	2.5 yrs	±3.3 yrs	7.3 h	±10.2 h	70.6	±11.0

user for digital storefronts like Steam, allowing these platforms to offer a larger variety of games, including ones that are very demanding on the hardware. Furthermore, the business models of the cloud gaming platforms are still in flux, as described earlier.

Game Ages The average game ages appear to be relatively high for all of the investigated platforms, and particularly so for PlayStation Now. It might be considered a special case, as it is specifically advertised as a backwards compatibility for older, pre-PlayStation 4 games that do not run on the latest Sony platform any more. For Steam, the distribution is significantly skewed towards recent titles: A quarter of games are less than a year old, and the median is at 21 months. The distribution's tail extends beyond 25 years due to re-releases of "classic" games on the platform.

Game Lengths Figure 1 shows the distribution of aggregated game lengths for the three platforms under investigation, and an "overall" distribution that includes further platforms and gaming systems. Among the three platforms, the median reported game length (approximately 9 h) is largest for GeForce NOW. In contrast to the curated choice of games on the Cloud systems, Steam also offers shorter and longer games. The "overall" dataset which includes further platforms spans a yet larger range.

Game Prices Trying to compare the prices per game is a difficult endeavor, due to the mixed approach of the gaming platforms. The GeForce NOW subscription gives customers access to a subset of its catalog that can be extended by purchasing additional games; GeForce NOW for PC and LiquidSky on the other hand require the customer to buy games on their own and pay for the time spent playing. PlayStation Now and PlayStation Now on PC have a flat rate for all of their catalog. At least for Steam, unit prices can be discussed.

Table 3 shows the development of average Steam game prices with standard deviations and the number of available games for all Steam measurements taken so far, spanning a time interval of more than two years. As can be seen, the number of games offered has more than doubled since the first data point,

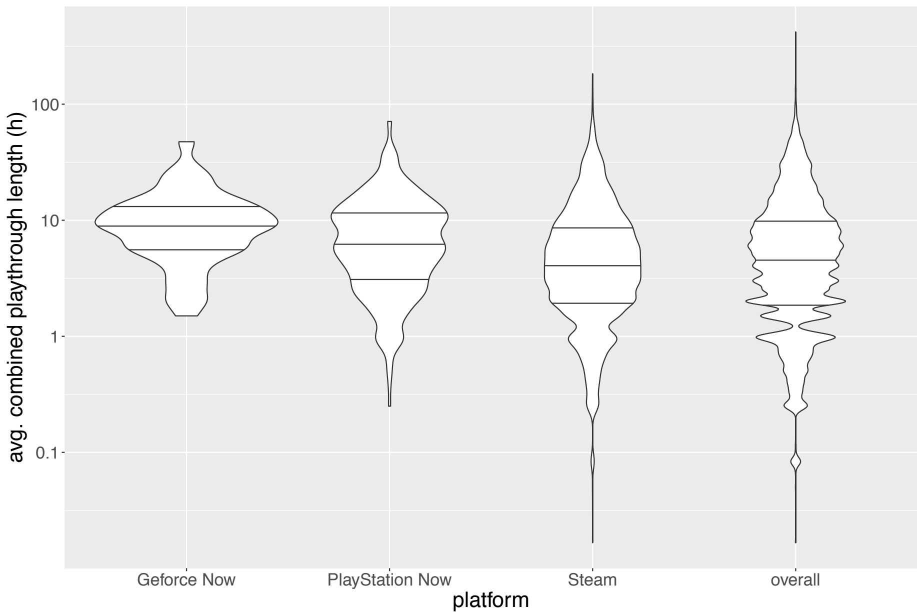

Figure 1. Violin plot of the per-platform average game lengths from How Long To Beat. Quartiles indicated by horizontal lines.

while the average prices fluctuate over time. The variability can be explained by Steam's regular offer of sales periods with reduced prices. For instance, the shift towards lower average prices in February 2016 coincides with a seasonal sales campaign for Lunar New Year[16].

Price versus Playtime Again focusing on Steam, Figure 2 breaks down the distribution of average playtimes per game price range. The game price ranges are chosen so as to roughly separate the prevalent modes of the price distribution.

[16] `http://store.steampowered.com/news/20313/`

Table 3. Overview of average prices and counts for Steam games.

Date	2015-07	2015-10	2016-02	2016-06	2016-09	2016-11	2017-04	2017-10
Average price (€)	10.11	8.47	5.65	4.72	8.77	5.33	9.95	8.83
Standard deviation (€)	±12.03	±9.74	±7.88	±7.02	±10.83	±11.08	±29.94	±12.2
Number of games	5,996	6,769	7,749	9,187	10,191	10,077	11,612	14,120

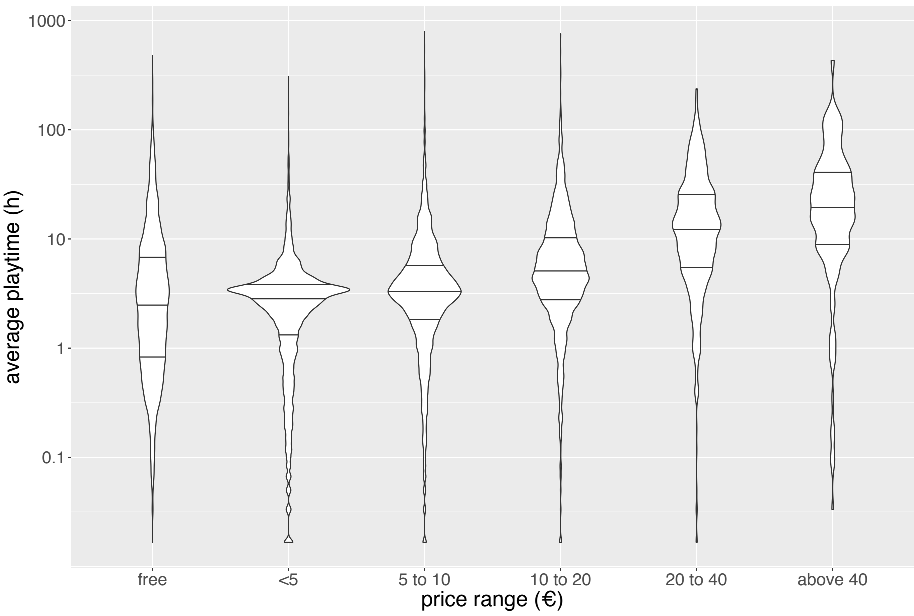

Figure 2. Violin plot of the average playtime of STEAM games, broadly categorized by their price ranges. The number of games per bin are 1541, 5269, 4019, 2445, 658, and 188. Quartiles indicated by horizontal lines.

Playtime is defined as the time game owners spend playing a game, as recorded by the STEAM platform and scraped from *SteamSpy*. On the far left in the Figure, playtimes of "free" titles (including free-to-play games with monetization options other than an upfront payment) span almost the whole playtime range with an inter-quartile range of 45 minutes to about seven hours. For games that cost less than €5, the mode is around 3.5 hours of playtime, and values are concentrate around it. The latter is of special interest because it is a recent trend that only manifested itself in datasets in the last ten months. It seems that game producers see this combination of price and playtime as a sweet spot, as the number of games in this price category grew by a factor of 2.4 in that timeframe — for comparison, the number of games increased by 37 percent in the free price range, and roughly doubled in the other price ranges.

Other than that, the median playtime increases with the price range; unfortunately, the data does not explain the cause: E.g., more expensive games might have more playable content, causing the playtime to increase. Conversely, higher upfront costs may incite players to spend more time regardless of game quality, thus avoiding regret for the expense. Due to the strong popularity of STEAM in PC gaming (even physical retail copies often require using the service nowadays) this set also gives a good overview of the dimensions of PC gaming in general.

Figure 3. Violin plot of aggregated review scores per platform. Quartiles indicated by horizontal lines.

Review Scores The final characteristic presented from the data are game review scores as given by professional gaming media outlets. This relies on the METACRITIC dataset. This set covers review scores for all current and historic gaming platforms. The review scores are aggregated to average scores ranging between 0 and 100. Some METACRITIC-internal weighing factors are applied to express the importance of some media outlets over others. The average scores seem quite similar across all services, albeit with a slightly lower σ for GEFORCE NOW. Figure 3 shows the distribution of review scores per platform. Both Cloud services seem to favor certain score levels, and their averages, medians, and third quartiles all exceed STEAM's. This could be an effect of the Cloud systems curating the game offer to focus on highly-rated (and thus perhaps more attractive) titles. STEAM on the other side is a more or less open platform, where every game publisher can sell their games at their own volition .The platform operator collects a commission fee for sales. Consequently, it is reasonable to assume more variation in the quality of games, which could in turn lead to mixed reviews.

5 Cost Utility Model

This section now turns to modeling gamer utility as a function of cost. The model assumes a utility proportional to the number of games playable, and expresses how many games a given budget will buy on the different platforms, as a function of the customer's budget. This basic model was chosen for requiring as few assumptions as possible; however, other utility metrics can be modeled from the data, e.g., the number of hours of gameplay that a given expenditure buys.

A few basic assumptions are made. The initial hardware costs per §3.1 are factored in proportionately to the expected life and depreciation time of the devices, which is assumed to be 3 yrs for PCs, and 6 yrs for the consoles and devices necessary to receive the streaming service. The difference in the service models between the ownership model of STEAM, the hybrid subscription plus permanent rental model of GEFORCE NOW, and the flat rate model of PLAYSTATION NOW were discussed previously already. Since it is difficult to express the different notions of "being able to play" and "owning" a game in simple terms, our utility model just considers the number of games that one has access to and could have played at one point. (This also ignores other means of acquiring games cheaper from alternative storefronts). Furthermore, there exists no pricing data for GEFORCE NOW games yet, so prices were extrapolated from the STEAM dataset for those titles that are available from both platforms. The numbers of games available per platform, the game prices, and subscription fees are considered as fixed at their current values.

Figure 4 shows that all platforms start with relatively high fixed costs, including hardware depreciation and subscription fees as applicable. The subscription models provide instant access to a certain amount of titles (visible as "steps upwards" in the available game count) which could make them attractive to newcomers on a low budget. On the other end, both cloud platforms exhibit plateaus due to the relatively small selection of games available. There, additional expenditures cannot buy further games. On the other hand, STEAM's offer of more than 14,000 titles is far from depleted in this picture, and its 1,500 free games could also be included in its affordable games count.

6 Conclusion And Future Work

This paper investigates the prospects of cloud gaming from a new perspective: game utility. Complementing the existing literature on technical and perceptual quality, it investigates the characteristics of the game catalog that cloud-based and software distribution gaming platforms offer, and discusses the customer benefit. For this, data from a number of sources are combined and evaluated: Game titles are scraped from the platforms (GEFORCE NOW, PLAYSTATION NOW, and STEAM), game lengths from HOW LONG TO BEAT, and summarized review scores from METACRITIC. The datasets used span a timeframe from 2015 to 2017, and are available from the authors' public repositories. The utility metrics proposed include the number (and thus variety) of games, playtimes, prices, review scores, and combinations of these, plus some historic aspects.

The gaming platforms are compared based on these metrics, and a cost utility model is presented that makes the different pricing policies (flat rate, subscription with included and surcharged games, or open à la carte) comparable between

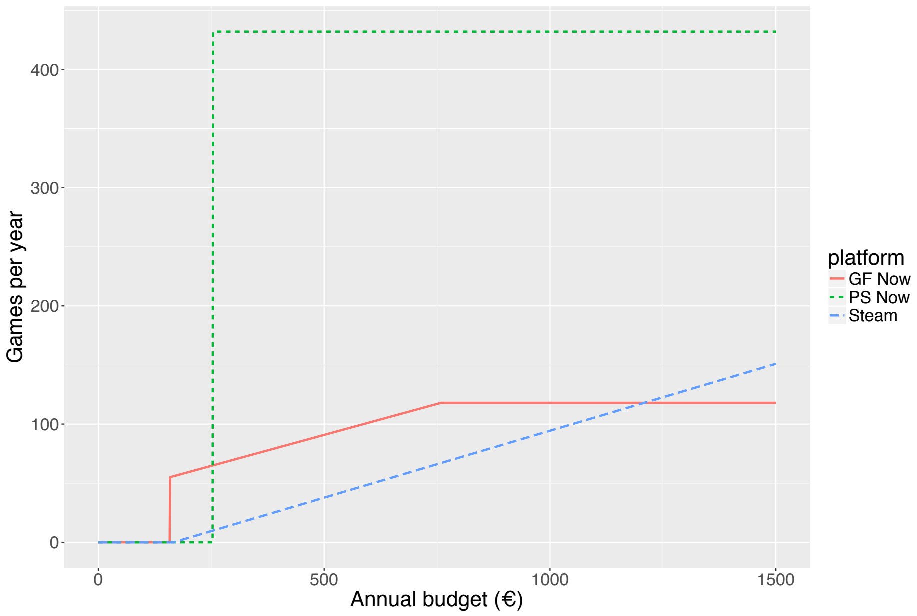

Figure 4. Affordable games per year on different platforms, given the customer's budget, assuming averaged prices and excluding free Steam games.

platforms. Currently, PlayStation Now's policy offers the largest number of games for annual spendings up to approximately €3, 000. However, note that the platform has changed its policy in 2017; it used a subscription/surcharge model like GeForce NOW before. Second, Steam's current catalog (while more expensive assuming the average game price) is 30 times larger than PlayStation Now's.

The dataset presented leaves many possibilities for future work. For example, many additional investigations of combined utility metrics and costs per platform are possible. Furthermore, it was mentioned that utility metrics may be interpreted differently. If the behavior of prototypical customers can be estimated from the dataset, then combined and comparable utility scores could be calculated. Also, the cloud rendering platforms deserve a closer look. Superficially, they currently serve but a niche market, and combine the negative aspects of subscriptions, usage-based billing, and per-game costs for a presumed gain in game QoE. It remains to be seen if there exist less apparent benefits for customers, or if the cloud rendering model fails to establish in the market.

Moreover, direct user studies can complement the data-driven approach followed in this paper. The utility metrics presented follow from the personal experience of the authors, but do not necessarily represent gaming public's opinion. Besides, self-reporting from game customers can explain conjectured effects like preferential attachment for popular games.

Finally, it would be interesting to investigate the operator-side issues of cloud gaming to understand their cost pressure better. Cloud gaming requires highly regional data-centers and specialized hardware to function well. This eliminates many of the efficiency gains that generic cloud services are intended for. The efficiency problem is aggravated by high regional peak (and consequent low average) utilization that require substantial infrastructure investments at limited scaling advantages.

At any rate, computer gaming and cloud gaming in particular will remain interesting topics for research in the years to come, as new business models and ways to consume games evolve.

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