A Case Study of the Software Engineering Principles Adopted by Media Streaming Services: Amazon Prime Video

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I. INTRODUCTION

With nearly 6 billion internet users worldwide in 2023, and a forecast increase to over 7 billion by 2028 [39], the internet is becoming more and more popular year on year. Connectivity provides users with access to resources and services, with the most popular internet uses related to finding information, maintaining relationships, and staying up to date with recent news and events [38]. One notable area which is experiencing rapid growth is the Subscription Video on Demand (SVOD) industry, with global revenue close to 100 billion USD in 2022 [37]. Amazon Prime Video (APV) is arguably one of the main contenders in this arena, with an estimated forecast of 167 million subscribers by 2025 [36], and offering over 31 thousand hours of content as of May 2023 [35]. A variety of movies, series, and live sports coverage are available through APV's subscription service, as well as the opportunity to access additional channel subscriptions like 'HBO Max' and 'Paramount+' directly from your APV account [10].

An APV subscription is currently available in two forms, either as a standalone product for £5.99 per month, or as part of an Amazon Prime subscription for £8.99 per month [10]. Prime members can access exclusive shopping discounts within the Amazon ecosystem; stream video with APV; read a selection of magazines, newspapers, and comics with Prime Reading; listen to over 100 million songs ad-free with Amazon Music; and benefit from free one-day delivery for millions of items on Amazon.co.uk [42]. These benefits included with a Prime membership have been cleverly designed to incline customers towards Amazon's ecosystem, increasing their attachment to the retailer "from both a cognitive and emotional perspective", and in turn, to "(reinforce) their impulsive buying behaviour" [34, p.8].

APV has recently seen large investments from Amazon, and has continued to grow exponentially as a result – Amazon Originals like 'The Marvelous Mrs. Maisel' have been immensely popular among viewers, and with their original content receiving 68 Emmy Award nominations in 2023 [13]. While perhaps originally intended simply as a draw to purchase a Prime membership and to increase Amazon's sales, APV has been increasingly successful year on year, forcing Amazon to change their revenue model to continue to increase their investments in the service. In 2024, "Prime Video shows and movies will include limited advertisements", with APV also giving viewers the option of an ad-free experience for an additional $2.99 per month in the US [13, Paragraph 3].

II. SOFTWARE ENGINEERING PROCESS

Amazon is constantly focused on maintaining their 'Day 1' culture and model – "one that is customer-obsessed, that enables high quality and high-velocity decision-making, and that empowers employees and leaders to stay curious, … and permit failure" [4, Section 4]. This 'Day 1' culture essentially encapsulates the Agile philosophy in different terms; Agile development is "a wide umbrella of software beliefs", which champions four main values: "individuals and interactions over processes and tools"; "working software over comprehensive documentation"; "customer collaboration over contract negotiation"; and "responding to change over following a plan" [16, pp.248-249]. There are several concrete ways in which Amazon enforces the Agile philosophy, or 'Day 1' culture, one of which is their 'two-pizza teams'. To minimise bureaucracy, maximise innovation, and allow quick decision making, Amazon believes that "no team should be big enough that it would take more than two pizzas to feed them" [3, Section 3]. These small teams have 'Single-Threaded Ownership' over a specific product or service, featuring a single team leader who's responsible for orienting team members, assigning work, and minimising distractions. Additionally, when teams become too large, or require a larger number of members to deal with increasing demands, the groups will undergo mitosis, and split into two or more appropriately sized groups which will each work on a subsection of the original problem. This team division process ensures that the workload is never too large for one group of developers, while also keeping teams 'agile' and responsive [3].

This emphasis on the importance of team size within Amazon is backed by research carried out in the 1970s, which found that participants were most comfortable in groups with three to four others [8]. In groups any smaller than this, group members may feel uncomfortable disagreeing with each other, leading to a lack of innovation and productive criticism. The same paper praises the increase in resources larger groups benefit from, and suggests the very same mitosis process that two-pizza teams within Amazon undergo to minimise coordination problems [8]. Another concrete example of their dedication to a 'Day 1' culture, and consequently to the Agile philosophy, is their process of 'Working backwards' – when designing a new product, team members will "draft a press release that announces the product … and an FAQ anticipating tough questions" [6, Section 1]. This obsession with customer experience follows one of the Agile philosophy's central tenants – customer collaboration over contract negotiation [16] – and the FAQ section could be likened to 'user stories', a similar technique for defining user requirements often used in the software engineering process. The technique involves "representing requirements using a simple template such as 'As a <role>, I want <goal>, so that <benefit>'" [33, p.209].

Changing scope from their parent company to APV themselves, in 2018 Prime Video moved from managing their videos using Customer Queue Service (CQS) built on Oracle,

to a collection of 12 microservices constructed using a range of tools provided by Amazon Web Services (AWS) [41]. AWS is yet another subsidiary of Amazon, providing a range of cloud-based technologies, such as "infrastructure technologies like compute, storage, and databases … to emerging technologies (like) machine learning and artificial intelligence, data lakes and analytics, and Internet of Things" [32, Paragraph 2]. AWS was created as a result of Amazon researching DevOps in the early 2000s, and now provides both Amazon and other customers a variety of cloud-based tools to allow them to power their businesses using a similar DevOps approach [43]. In their whitepaper 'Introduction to DevOps on AWS', the web services subsidiary company defines DevOps as "the combination of cultural philosophies, engineering practices, and tools which increase an organization's ability to deliver applications and services at high velocity and better quality" [12, Paragraph 3]. They also provide a list of practices they deem incredibly important to a company's journey putting DevOps into practice: "continuous integration and delivery", "infrastructure as code", "monitoring and logging", "automation", and "communication and collaboration" are among the top-ranked practices according to Amazon's web services provider [12]. For Amazon Prime Video to make effective use of AWS's services, they will be regularly committing code to a centralised repository, automating the building and testing of software systems before release, and observing and documenting software performance [12], all while keeping teams close and distributing responsibilities appropriately using their two-pizza team model.

Amongst the variety of tests APV's system is subjected to, like other large, distributed services, they have decided to make use of 'Chaos engineering' to prepare for and mitigate potential disasters before they happen. This testing process involves "experimenting on a distributed system to build confidence in its capability to withstand turbulent conditions in production … (this could involve) anything from a hardware failure, to an unexpected surge in client requests, to a malformed value in a runtime configuration parameter" [11, p.1]. Reference [7] details a case study which focuses on APV's use of chaos engineering in May 2020 to detect a bug in their countermeasure software, and consequently prevent a potentially disastrous failure of their system. Setting out to engineer unexpected and unfortunate incidents within the system and responding to the artificially produced effects is a fantastic technique to prevent unexpected service outages for customers, and consequently has been adopted by a variety of large tech organisations [7]. If Amazon Prime Video manages to continue to implement Amazon's Day 1 culture effectively - implementing their Agile philosophy, two-pizza teams, and microservice-based software architecture model as intended – they should continue their frictionless scaling and growth. From their 'working backwards' approach to the initial inception of their products, to the DevOps principles they hold to be invaluable, to their focus on powerful testing tools and their insistence on effectual communication between team members; the Amazon Day 1 philosophy ensures that their software engineering practices and goals remain relevant and suitable for the systems they develop.

III. ETHICS

When considering the production and use of a media streaming service from an ethical perspective, one of the main concerns that might arise is the effect that binge-watching can have on users. Binge-watching has been defined as watching several episodes of a TV show in a single sitting [2]; however, this definition is somewhat loose, and researchers have noted that it allows over-pathologisation of what is a common behaviour [9]. For the purposes of this paper, we will consider binge-watching to be the second manifestation of this common behaviour, uncovered in [9]'s systematic review of the current literature: "an excessive/problematic behavior not only associated with negative outcomes, but also with a range of risk factors associated with dysfunctional use of technologies (e.g., age, underlying coping motives, impulsivity, automaticity) and diverse mental health conditions" [9, p.14]. Some of the 'negative outcomes' referred to by the definition above include poor sleep, fatigue, reduced cognitive control, and ineffective emotional regulation [15]. The phenomenon of binge-watching is a complex and multifaceted subject, difficult to define, let alone mitigate; nevertheless, APV would do well to implement some reminders and screen-time limits, similar to the push notifications and limits TikTok now offers [31]. After all, not only would reminders and limits help fight binge-watching and the negative symptoms it helps produce, but they could also increase average subscription length and reduce the number of subscribers who 'binge and bail' [30]. Another ethical concern regarding services that enable media streaming might be the carbon footprint viewers incur – however, the media streaming industry's carbon production is negligible when compared to other industries. Reference [29, Section 6] found that "Powered by the global average electricity mix, streaming a 30 minute show on Netflix in 2019 released around 18g of CO_2", around half the CO2 released by boiling a kettle. While urging viewers to watch media in lower resolutions may benefit the climate to some degree, time may be better spent asking users to drink a cold cup of tea instead.

Perhaps more ethically ambiguous is APV's parent company, Amazon – staying on the topic of the climate, over 8700 Amazon employees signed an open letter to Amazon's CEO and the Board of Directors in 2019, requesting that Amazon adopts an improved company-wide climate plan, and stating that their "customer obsession requires climate obsession" [28, Paragraph 11]. Amazon responded by pledging to reach net-zero carbon emissions by 2040, along with a webpage dedicated to displaying eco-positive statistics [14]. It is unclear how many of these actions, if any, are a form of 'greenwashing' intended to boost market value, but if they are, it is to the detriment corporate's relationship with their employees [5]. Amazon has a variety of other ways in which they have arguably avoided fulfilling their corporate social responsibility (CSR), including but not limited to: Tax avoidance [27]; Excessive director's payment [26]; Anti-unionising spending [25]; and Child privacy violations [24]. As [1] notes, an organisation of Amazon's size will naturally struggle with the effects of their globalisation, and respecting the rights of every employee. However, the authors state that Amazon "are truly working to make society a better place", and that their environmental measures "are generally good" [1, p.15].

IV. CRITICAL ANALYSIS OF THE SYSTEM, AND A COMPARISON WITH NETFLIX

APV implements a layout and user interface much like many other streaming services available today, with a home page being used to display the most popular content to users, along with access to search functionality, and a vertical

sidebar navigation menu [22]. Reviewing APV's advertised sign-up page, there are three main features that are used to attract customers: the ability to watch content from a variety of devices, the ability to download content to watch later, and APV's 'X-ray functionality' [20]. While the ability to stream media on "smart TVs, game consoles, mobile phones, selected tablets, (and) laptops" [20, Section 2] and downloadable content certainly isn't unique to the APV system, its 'X-ray' feature is somewhat more remarkable – this feature provides users with information regarding cast and actors, trivia about specific scenes, bonus content, and the ability to discover what music is playing in the background of media content, all while continuing the viewing experience [21]. This feature is unique to the APV system, and will certainly be a selling point for investigative viewers and movie fanatics alike.

APV's recommendation algorithm is also worthy of note – it uses deep neural networks which consider similarities at the item level, rather than the user level [19]. Moreover, the algorithm gives additional weighting to recently released content, as Amazon researchers found "most movie watchers will probably opt for recent releases over neglected classics in their preferred genres" [19, Section 5]. APV provides many titles in 4K quality, and offers a variety of accessible keyboard shortcuts to play / pause, enter full-screen, fast-forward and rewind, increase and decrease volume, and toggle the mute, subtitles, and captions functionalities [18].

When comparing APV to Netflix, there are arguably more similarities than differences. Both systems have similar user interfaces, playback controls, and search features; however, Netflix provides just under 8,000 extra hours of content for UK viewers as of May 2023 [35]. In a comparative analysis of the two systems carried out in 2020, users reported that they preferred Netflix's user interface and the additional available features like trailer playback and parental controls [23]; however, APV has since added these features and improved their user interface, such that these complaints may no longer apply [22]. While there are some minor system-level differences, such as Netflix's lack of an 'X-ray' feature, the main differences between the services come down to viewer preferences regarding exclusive original content, and importantly, pricing plans. Netflix offers three tiers of subscription, with the highest quality video and audio streaming capabilities available only to premium users. Since the premium subscription is available at £15.99 per month, potential customers might consider the benefits of a full Prime membership at £8.99 per month, with 4K viewing capabilities at no extra cost, to be more attractive [17].

V. Future work

It is difficult to identify any singular area in which the system of APV is deficient when compared to competitors in the market. While recent changes to their UI have been well-received [22], user preferences and requirements regarding system interfaces will continue to change and evolve over time along with technological trends. Similarly, changes in service architecture will reflect the most efficient and cost-effective options available to Amazon, as reflected in APV's recent adoption of a monolith application to monitor streams [40]. Increased levels of video and audio quality are to be expected as recording and distribution services improve, and further research will be carried out regarding the optimisation of algorithmic suggestion of content to viewers [19]. Continued investment in original, exclusive content might be wise for

APV going forward, as this is often the deciding factor for customers considering which service to join.

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