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In Defense of the Broader Application of Virtual Queues

Evan Rapone

Introduction

Queuing is an inevitability. Nearly any service offered to customers requires that they wait in line at some point during the process of being served. Queue lengths may depend on a number of factors: the influx of patrons entering the line, the capacity of the provider to serve customers, and the efficiency in meeting the demands of the clients. The primary issue facing businesses is that superior quality of service alone is no longer sufficient for consumers; clients also want speed (Katz et al.). Americans live in a work-centric society with an innumerable amount of strains on free time (Katz et al.). Due to these externals demands, consumers believe leisure time is too valuable to be wasted, which translates into an intolerance of waiting of any kind (Katz et al.). With centuries of knowledge and technological development contained in the smartphones that consumers may use at any given moment, an aversion to waiting is not surprising. Yet, the ease of accessibility to this virtual information appears to be attributed to the lack of physical constraints associated with the source; virtual sources often seem faster because consumers can pursue other activities while waiting (De Lange et al.). We have arrived at a peculiar point in time where the physical world appears to be lagging behind the virtual world. Rather than accept the notion that the former may never catch up to the latter, we can attempt to propel the tempo of the operation of the physical world foward.

In accordance with the disdain for waiting in physical queues, we may look for a virtual solution to expedite the provision of a service or, at the very least, shorten our perception of the duration of the wait. Virtual queues can be considered to be “invisible” queues that function similarly to standard lines, but do not require customers to physically maintain their position in line (De Lange et al.). The individual ensures his or her placement in the queue, whether by means of accessing a particular webpage, acquiring a certain ticket, or arriving at a specific location. From that point forward, the progression of the individual through the queue is accounted for by a computer, eliminating the necessity of remaining in the same location until the duration of the wait is completed. Clients will be alerted once a provider is available to serve them, and they can return to the original location in which their wait began. Perhaps one of the most rudimentary examples of this system, many restaurants use a pager system to alert patrons when a table is available (Kimes). Customers approach the hostess stand, provide their name and party number, and are offered an expected wait time as well as a pager that will vibrate when the consumers can be seated (Kimes). Customers are free to wait inside the lobby, outside the restaurant, or, when accessible, at a bar in the restaurant (Kimes). Although the freedom of movement has an immediate benefit for the customer, the system is also beneficial for the establishment in mitigating overcrowding near the entrance and offering patrons additional avenues for the purchase of products (Kimes). The restaurant pager example does not provide a perfect representation of the virtual queue, but the implementation does demonstrate that the physical world can benefit from such an application.

The purpose of this paper is to expand upon the successes of the implementation of virtual queues. A direct attempt to harmonize the world of theme parks and the everyday world will be conducted. Though the two almost always appear mutually exclusive, this work will demonstrate that the separate worlds are more intimately linked than initially believed. Akin to the world beyond theme parks, queuing is a necessity for any and all attractions. Conversely, the theme park industry has made considerable changes to their queuing methods to streamline waits, which will be examined later, whereas the everyday queues experienced at a business remain untouched. Thus, theme park queuing methods can serve as a model for improving other queues due to the extensive number of modifications. Specifically, the potential utility of a revised queuing system that unites virtual queues with physical queues will be examined. I will begin with a discussion of the current state of queuing theory, examining the general principles and current limitations of the field. I will then introduce the FastPass system, which is a method of queuing employed at various Disney parks in which physical and virtual lines are combined to better regulate the operation of the queuing process. I will then discuss the proper means of applying a virtual queue to various physical services as a solution to improve queuing theory. I will argue that, according to the principles of the FastPass system, providing patrons the choice of waiting in a virtual queue or continuing in a traditional line is a self-regulating process that will prove to be more successful than the current queuing systems. I will present a representative case study in support of the application of such a queuing method. Finally, I will review a number of limitations in the realistic implementation of virtual queues.

Queuing Theory Discussion

A wide variety of line models have been developed to describe the formation and progression of various queues (Anderson et al.). Prior to discussing some of the most commonly-enacted models, a review of queuing notation must be presented. Developed by D. G. Kendall, the standard notation used to describe and classify queuing models is known as Kendall's notation (Cope et al.). Kendall's notation incorporates three symbols to describe the general operation of a queue: $A/B/k$ (Anderson et al.). A signifies the probability distribution for the arriving customers, B represents the probability distribution for the service time, and k denotes the total number of servers present (Anderson et al.). The power of Kendall's notation is attributed to the variety of queuing systems that can be described in the *A* and *B* positions (Anderson et al.).

The letter *M* can represent a Poisson probability distribution for arriving customers when written in the *A* position or an exponential probability distribution for service time when written in the *B* position (Anderson et al.). For example, a Poisson distribution of arrivals corresponds to a random influx of customers (Beasley). Successive customers arrive after independent intervals, and each interval is exponentially distributed (Beasley). In short, the time between one customer arriving and another is not affected by the amount of time that has passed since the last customer arrived. A large gap in time between arrivals does not make the next arrival any more or less likely. The Poisson stream is particularly useful because the distribution is described by a singular parameter, the average rate of arriving customers (Beasley). For this reason, Poisson distributions are important in modelling many real life queues (Beasley).

Two other letters commonly appearing in the *A* and *B* positions in Kendall's notation are *D* and *F*. The letter *D* represents arrivals or service times that are fixed (Anderson et al.). Unlike the Poisson process, which considers average arrivals or service times, this line system can maintain a constant influx of customers or service time (Anderson et al.). The letter G designates a general distribution of arrivals or services times (Anderson et al.). The mean and variance of the distribution are known, but the overall influx of customers or service time distribution is arbitrary and unknown (Anderson et al.).

One of the simplest and most commonly described forms of queuing is a single-server line system in which both customer influx and service time are modeled by a Poisson distribution (Anderson et al.). Such a model is described as *M*/*M*/1 using Kendall's notation (Anderson et al.). Recent applications of Kendall's notation have introduced additional symbols to account for more complex line systems (Anderson et al.). For example, a fourth symbol may be used to describe lines that can only hold a certain number of customers and a fifth symbol may be used to represent an arrival rate for a finite population (Anderson et al.). In many cases, the three symbol form of Kendall's notation is appropriate because line systems are oftentimes assumed to have infinite capacity to accommodate arrivals from an infinite population (Anderson et al.).

Table 1 presents four examples of common line structures that can be described using Kendall's notation (Cope et al.). To clarify the vocabulary of each title, channel refers to the number of servers in parallel that can serve a customer, and phase designates the number of servers in sequence that a customer must pass through (Cope et al.). Most queuing systems in businesses as well as lines for theme park attractions are classified into one of these line forms (Cope et al.).

Table 1

Line Structures	**Example**
Single-Channel, Single-Phase	Drive-thru food pickup
Single-Channel, Multi-Phase	Automatic car wash
Multi-Channel, Single-Phase	Hotel reception
Multi-Channel, Multi-Phase	Hospital service

Table 1: Commonly-used line structures and corresponding examples of each. Many queuing systems in businesses can be classified into one of the categories (Cope et al.).

In short, queuing theory involves the mathematical analysis of various system such as the aforementioned line structures (Taha). In place of optimizing models, the mathematical analysis is performed to measure the effectiveness of queues, which may take into account the expected wait time per arrival or the percentage of time a server spends idle (Taha). The measures of effectiveness are used to optimize the capacity of the server, which oftentimes involves optimizing costs (Taha).

Despite the perceived benefit of queuing theory, the application of the analysis is often difficult (Taha). Queuing models in practice display two primary complications: the ease of representing the system by a mathematical model and the flexibility of the model (Taha). Standard forms of queuing are typically categorized in three ways: human systems, semi-automatic systems, and automatic systems (Taha). Human systems involve services in which both the customer and server are humans, and automatic systems involve services in which both the customer and server are non-human (Taha). Semi-automatic systems designate services in which either the customer or server is human (Taha). Human systems are the most common forms of queuing, but are also the most difficult system to mathematically describe due to the varying interests of both server and customer (Taha). While these systems might be "doctored" to influence customers to follow a certain pattern, such as airport check-in lines switching from many single-channel, single-phase queues to one multi-channel, single-phase queue, these modifications are only effective to the extent that human behavior conforms to the model (Taha).

Second, after establishing a suitable mathematical representation of a queue, the model may not always be flexible (Taha). Such issues might be manifested in two forms: difficulty in solving the model despite knowing arrival and service times, or difficulty in obtaining numerical results from the model due to the number of variables describing the system (Taha). With improved computing technology, the latter issue appears less pertinent than the former (Taha). Two attempts at accounting for issues in solving mathematical models can be made: first, simpler models can be use and second, approximations of other models can be used (Taha). In place of developing complex mathematical models with a number of variables to consider, businesses can use simpler, more flexible models such as Little's law (Little). Little's law is simply written as $L=\lambda W$, where L represents the average number of items in a system, λ denotes the average arrival rate of items, and W indicates the average wait time of an item (Little). In the context of this paper, Little's law states that the average length of a queue in steady state is given by the product of the rate at which customers enter the line and the average amount of time they spend in line (Simchi-Levi and Trick). Despite the perceived simplicity of the formula, Little's law is powerful because the relationship is not dependent on the distribution of arriving customers or service time. (Simchi-Levi and Trick). Even further, Little's law holds for any service order or queuing principle (Simchi-Levi and Trick). An application of Little's law can provide a simplified analysis of complex systems by explicitly examining just queue length and wait time as opposed to considering a number of other factors (Simchi-Levi and Trick).

Despite the benefits of Little's law, such a highly flexible model is not often used in queuing theory because the analysis is perhaps too simplified to provide an accurate representation of queuing models (Taha). Little's law may still function well in serving upper levels of management in overviewing ongoing operations (Little). Although Little's law relates three distinct average statistics, each value is a clear measure of the effectiveness of a process (Little). Any fault in the system would likely be manifested in at least one of the averages (Little). In place of relying on simplified models like Little's law, another method of improving model flexibility incorporates approximations. Specifically, certain forms of queuing, such as the $M/G/1$ model, can be approximated by simpler forms, such as the $M/M/1$ model (Taha). In doing so, a general distribution of service time is approximated by an exponential distribution (Taha). The degree of flexibility of the approximation is provided by the percentage error in the expected number of items in the system (Taha).

Although businesses may partially be able to address the ease of representation and flexibility of models, the analysis still abounds with a series of problems (Byrd). Most theories regarding queuing account for steady-state conditions, as in the case of Little’s law (Byrd). Businesses do not appear to operate as frequently under steady-state conditions as queuing theory would imply (Byrd). For example, businesses such as restaurants can vary the number of servers, the service time, or other parameters that account for fluctuations in the arrival rate of customers (Byrd). These factors are not accounted for by the traditional methods of queuing theory as previously discussed. Additionally, service times may not always be defined (Byrd). In a number of cases, such as a retail store, the type and duration of a service can vary between servers (Byrd). Perhaps the biggest issue with queuing theory is that such analysis does not accurately account for multi-channel, non-exponential service time distribution, which oftentimes is the most representative example of a real-life service (Byrd). As mentioned, the $M/G/1$ form of queuing can be problematic in solving for a mathematical model and may require approximations of simpler models (Taha). The application of queuing theory does not offer a manageable, alternative method of solving such a model (Taha, Byrd). As such, queuing theory appears to function better as just an analysis of a system than as a model for improving the system.

The limitations of queuing theory should not impede attempts to improve the queuing process. Instead, businesses can look to Disney for the next step in providing better efficiency during the queuing process (Cope et al.). Queuing is a tradeoff for businesses; managers need to find an equilibrium between the pressures of wait time and potential revenue gain (Cope et al.). In effect, every minute that customers spend in line is a minute that they are not generating revenue for a business (Cope et al.). A primary goal of the Walt Disney Company has been to optimize revenue by means of balancing capacity costs with the costs of not maintaining sufficient capacity to serve guests (Cope et al.). The application of virtual queues by means of the FastPass system has helped to eliminate the necessity of waiting in a physical line to allow guests to engage in other activities, which may include pursuing additional purchases (Cope et al.). By offering such a service, Disney can generate considerable additional revenue. For example, Cope, Cope, and Davis sampled four popular attractions at Walt Disney World to analyze the potential benefit of allowing a certain percentage of guests to pursue the FastPass option (Cope et al.). Table 2 displays the four chosen attractions as well as the approximate hourly capacity of each.

Table 2

Attraction	**Approximate Capacity**
Pirates of the Caribbean	2,500
Haunted Mansion	3,200
Space Mountain	3,400
Soarin'	1,050
All four attractions	10,150

Table 2: Four popular attractions at Walt Disney World and the corresponding approximate hourly capacity of each. In addition, the total capacity of all four attractions is presented. Data has been retrieved from *Theme Park Insider* and *Ultimate Orlando* (Cope et al.).

Theme park attractions do not always operate at perfect capacity; demand fluctuates throughout the day and each ride requires a certain amount of time to load and unload guests (Cope et al.). Table 3 presents various, rated capacities based on the potential load demand factors (Cope et al.). In addition, Table 3 displays the number of guests that could be displaced from the standby line using the FastPass system, which assumes a pass distribution amount based on 50% of the capacity of each attraction (Cope et al.).

Table 3

Condition	**70% Capacity**	**80% Capacity**	**90% Capacity**	**100% Capacity**
All guests in line	7,105	8,120	9,135	10,150
50% displaced	3,552	4,060	4,567	5,075

Table 3: Rated capacities of the sampled four attractions. Assuming a FastPass distribution amount based on 50% of ride capacity, the number of guests that may be displaced from the physical line is also presented (Cope et al.).

Using the number of guests displaced by the FastPass system, deterministic estimates of the amount of additional revenue generated by the system can be made (Cope et al.). Specifically, Table 4 presents the amount of additional revenue earned per operational capacity for various levels of expenditure (Cope et al.).

Table 4

Additional Expenditure	**Revenue at 70% Capacity**	**Revenue at 80% Capacity**	**Revenue at 90% Capacity**	**Revenue at 100% Capacity**
$5.00	$17,760.00	$20,300.00	$22,835.00	$25,275.00
$10.00	$35,520.00	$40,600.00	$45,670.00	$50,750.00
$15.00	$53,280.00	$60,900.00	$68,505.00	$76,125.00
$20.00	$70,040.00	$81,200.00	$91,340.00	$101,500.00

Table 4: Deterministic estimates of additional revenue for the rated capacities of the sampled attractions. Potential revenue is presented for various levels of additional expenditure (Cope et al.).

In effect, the implementation of the FastPass system allows guests to create a multi-phase queue system that is personalized to their own interests and can be applied to either single or multi-channel lines (Cope et al.). By implementing the option of a virtual queue, Disney has added considerable flexibility to the queuing process without disrupting the traditional queue while also providing the company additional sources of revenue (Cope et al.).

Analysis of FastPass System

The concept of queue-less attractions at Disney had originally been developed as early as the mid-1970s, but reliability fears regarding the broader application of such a system forced the company to abandon the project shortly thereafter (Nelson). Despite the simplicity of FastPass, the system has only existed for approximately two decades, with many of the early years only permitting FastPasses to be distributed for certain attractions (Nelson). At the most basic level, guests have the ability to schedule a one-hour window to visit an attraction in which they can bypass the standby queue and proceed directly to the attraction, which is a much quicker process than if they had waited in the physical line (Dickson et al.). For the purpose of this paper, a review of the history of the FastPass system is important for two reasons: first, to analyze the basis for the development and expansion of the system and second, to acknowledge the deficiencies and limitations of the implementation of FastPasses. An analysis of the latter should demonstrate that most of the concerns held by Imagineers, the official name for members of the Disney creative department, are more applicable to theme parks than real-world services.

When Disneyland opened in 1955, the Walt Disney Company anticipated that approximately 11,000 guests would attend the grand opening (Nelson). Instead, over double that figure attended, and employees struggled to accommodate the arrival of over 28,000 guests (Nelson). The theme park was underdeveloped and ill-prepared for the plethora of arrivals (Nelson). During the first year of operation, switchback queues were installed outside of attractions to better organize guests and reduce the chaos of queuing (Nelson). Switchback queues incorporated rows of interlinked, metal chains that directed guests back and forth along the front of the attraction from the main pathway to the loading station (Nelson). The maze-like line was highly efficient and required minimal space to install (Nelson). Switchback queues also gave rise to the first, genuine concept of the "psychology of queuing," a notion defined by Professor Richard Larson of Massachusetts Institute of Technology (Nelson). The purpose of the switchback queue was to most effectively channel guests to the loading platform of an attraction, but an added benefit of the method was that, by design, the queues disguised the truth length of the line (Nelson). Since the chain-link rows alternated back and forth, the queue provided guests the illusion of there being many short lines as opposed to one long line, an effect that can be observed in Fig. 1 (Nelson). Switchback queues helped to manage the initial chaos of queuing during the early years of Disneyland, but the fundamental issue of reducing excessively long lines was not addressed (Nelson).

Figure 1: Photograph of switchback queue outside Alice in Wonderland ride (1959). This style of queue helps to disguise the true length of a wait by creating the illusion of multiple shorter lines (courtesy of *Daveland Photography*).

To combat increasing queue lengths, the Walt Disney Company introduced the ticket book system three months after the grand opening of Disneyland (Nelson). In place of a pay-per-ride system, visitors had the ability to purchase a collection of tickets that corresponded to specific attractions of different value (Niles). When the system was first introduced, there were three tiers of attractions: A, B, and C (Nelson). The A classification signified a smaller and/or unpopular ride whereas the C classification signified the more desirable attractions (Nelson). The system quickly expanded to include D and E tickets in 1956 and 1959, respectively, to account for an increasing number of attractions in the park (Nelson). Since guests could purchase books of mixed tickets as opposed to just individual tickets for specific attractions, the Walt Disney Company intended for visitors to be more receptive to riding the less popular attractions (Niles). Imagineers posited that encouraging the exploration of less popular attractions could balance wait times and cut down on excessively long queues (Niles). Guests still retained the option to purchase higher level tickets individually, but the monetary value of the ticket books compared to the relatively expensive D and E tickets oftentimes resulted in guests electing to diversify their experience to include all attractions (Niles). Table 5 displays sample ticket prices from the year 1969 as well as a representative attraction for each tier.

Table 5

Ticket Tier	**Price**	**Representative Attraction**
A	10c	King Arthur Carrousel
B	25c	Swiss Family Tree House
C	35c	Tomorrowland Autopia
D	60c	Tom Sawyer Island Rafts
E	75c	Pirates of the Caribbean

Table 5: Prices for each ticket tier at Disneyland in 1969. A representative attraction of each ticket tier is also presented (prices courtesy of *Vintage Disneyland Tickets*).

All factors considered, the system resulted in moderate success (Nelson). While the system appeared to better disperse crowds throughout the park, guests typically spent more time waiting in line for attractions than before, which meant they had less time to purchase additional ticket books, souvenirs, or other products (Nelson). In addition, many visitors would still ignore the lower tier attractions despite the fact that tickets for those rides had already been included in the purchase of a ticket book (Niles). The first genuinely concerted effort by the Walt Disney Company helped to shorten wait times through improved crowd distribution, but increasing crowds and increasing expectations of guests led Imagineers to shift the focus of their queuing philosophy.

Coinciding with the expansion of the ticket book system, the Walt Disney Company began making a number improvements to their queues with the intention of making the waits seem shorter (Nelson). To start, Disneyland introduced roaming characters and travelling refreshment stands to queues by as early as 1961 (Nelson). Guests were beginning to be provided a number of distractions to help them pass the time in line. In an effort to offer guests a more reliable experience, signs with wait times were added to the front of queues as well (Nelson). Although the preliminary application of this system was based more on judgment than actual science, the addition of wait times allowed guests to have more information and a better opportunity to plan their day (Nelson). Despite the perceived benefit of these additions, they did not resolve the two primary issues of guests, specifically that most queues were not themed and that they were open-air (Nelson). In essence, waiting in line was a boring process and left guests vulnerable to inclement weather. Imagineers realized that to most effectively meet the desires of guests, queues needed to be aesthetically pleasing to effectively distract guests (Nelson). Themed queues were developed to reduce the perceived wait time of a line by immersing guests into the story of an attraction (Nelson). Murals, decorations, and other features were added to elevate the status of the queue from being the means by which guests are transported toward the loading platform to being an integral component of the storytelling process (Nelson). Attractions that opened in the 1960s and beyond also incorporated pavilion style enclosures to shield guests from the weather (Nelson). These types of queue modifications appear to have been inspired by the original design of the *Jungle Cruise* queue, which debuted during the grand opening of the park (Nelson). An awning made of straw had been included above the queue to shelter guests as they approached the boat (Nelson). As an extension of this design, lines became unique to the attractions they served and offered protection and comfort to guests (Nelson). Every component of the queue was now designed with meaning and intent, and every aspect was intended to distract guests. Despite an underdeveloped inception, the queues at Disneyland had been transformed into relevant and exciting experiences that reduced the perceived duration of a wait.

Economic factors such as the 1980s recession as well as increasing competition from companies such as Six Flags led the Walt Disney Company to abandon the ticket book system in 1982 (Nelson, Niles). To generate more revenue, an all-inclusive main gate ticket was introduced, which offered guests unlimited access to all attractions (Nelson). Whereas a standard ticket book in 1980 would have costed approximately $8.50 per person and provided access to 11 attractions, including four E-ticket rides, the main gate pass introduced two years later costed $12.00 (data courtesy of *The History of Disneyland Tickets*). The previous successes of crowd redistribution offered by the ticket book system were lost as a result of the fact that guests were no longer encouraged to explore less popular attractions since they had unlimited access to more desirable rides (Niles). In addition, while the efforts in shortening the perceived wait time were not completely negated, the introduction of the main gate pass diminished the effectiveness of themed queues (Niles). For unpopular attractions, guests could rapidly pass through the empty queues and ignore the expanded storyline, whereas for popular attractions, no amount of design or aesthetic appeal could effectively distract from the increasingly long waits (Niles). To accommodate the longer lines and a shorter desire to wait in them, the Walt Disney Company introduced the FastPass system as an updated form of crowd management (Niles). The system is still being modified today, for example in shifting to the use of a phone application to store FastPass by means of the FastPass+ system, but the general operation of FastPass has remained constant: guests are able to retrieve a return window for an attraction in which they can bypass waiting in the standby line (Nelson). In effect, visitors can wait for an attraction while not being physically confined to the traditional queue. From here arises the concept of a virtual queue, in which the position of a guest in line is maintained by a computer rather than themselves. The FastPass system has been remarkably effective in alleviating long queues (Nelson). Through the first five years of inception, the system cut standby waits of FastPass-eligible attractions by approximately 40% (Nelson). Instead of trying to make waiting in line less of a nuisance, the Walt Disney Company had begun the process of eliminating the lines altogether (Nelson). Though the introduction of the main gate pass resulted in a return of the same crowd distribution problems that plagued the early years of Disneyland, the premise of encouraging guests to explore less popular attractions, which was derived from the ticket book system, fostered a more successful service in the FastPass system. Fig. 2 presents a chart summarizing the progression of the queue modifications that have led up to the inception of the FastPass system.

Figure 2: Chart summarizing the progression of queue modifications made by Disney. Major developments that have led up to the creation of the FastPass system are highlighted.

The implementation of the FastPass service offers guests a twofold benefit. First, the system more effectively distributes crowds throughout the park (Nelson). Guests may retrieve a FastPass for a popular attraction and then wait in the standby line for a less popular attraction, which maximizes their use of time throughout the day (Niles). Guests can then return to the attraction during the designated timeframe provided by the FastPass and proceed directly to the loading platform (Nelson). The rigid return window ensures that guests need to be mindful of timing when exploring other parts of the park during their wait. Second, the system is self-regulating (Dickson et al.). For example, if too many individuals avoid the standby line in favor of getting a FastPass for a later return time, the traditional queue will shorten to the point of eliminating the benefit of getting a FastPass (Dickson et al.). Expectedly, guests will pursue the queue option that provides them the shortest wait time, which will result in the two lines stabilizing (Dickson et al.). The system works since visitors have the *choice* to pursue the FastPass option (Dickson et al.). Forcing all guests to use a FastPass would result in the same issues as forcing all guests to wait in a standby line; crowd distribution would be unequal and guests would overcrowd areas as they wait. The option of standby or FastPass allows guests to make what they perceive to be the most beneficial decision in accordance with the rest of their plans for the day (Dickson et al.). In addition, FastPasses are distributed based on a percentage of the hourly capacity of the attraction (Dickson et al.). The preset allotment both guarantees adequate capacity to accommodate guests with FastPasses and ensures the necessity of the standby line to fill the remaining capacity (Dickson et al.). In total, the freedom of choice offered to guests encourages more efficient crowd and wait time distributions.

Despite the benefit of the FastPass system, the queuing method results in a few disadvantages. A primary concern of Imagineers is that guests are more concerned with the time than their experience (Nelson). Visitors oftentimes maintain the sole objective of getting through an attraction as quickly as possible; the aesthetic and the story of an attraction are ignored in favor of rapidly passing through the queue to make the most efficient use of time (Nelson). A further extension of this result, guests ironically have too much free time (Nelson). Although guests have the option to wait in a different standby line while in possession of a FastPass for a separate attraction, not all visitors will pursue this option (Nelson). Thus, the resulting crowds have a tendency to linger in locations designed for constant movement, which may block other guests from accessing certain areas near attractions (Nelson). Finally, the current trend of the development of the FastPass system encourages guests to plan their schedules months in advance of arriving. Instead of retrieving FastPasses in the park after observing the length of the standby queue, guests may now select their preferred rides prior to arriving at the park. This possibility can inhibit the self-regulatory nature of the FastPass system. When all FastPasses have been distributed for a given attraction, guests lose the ability to choose between waiting in a physical or a virtual queue. By this process, the general principle of the FastPass system, that guests choose the shortest possible queuing method, has been eliminated. While the problem of overscheduling can pose a direct threat to the operation of the FastPass system, an argument will later be presented that the prioritization of timing is inconsequential and easily addressed outside of the theme park.

Two Common Queuing Principles

Prior to projecting the successes of a FastPass-like system outside of theme parks, two of the most common, preexisting queuing principles will be discussed, namely a first-come, first-served (FCFS) system and a reservation system. Included in this analysis will be a review of the successes of both systems and a rationale for why, as a standalone, neither method is an optimal method of queuing.

The first-come, first-served system is generally considered by customers to be the fairest form of queuing (Dickson et al.). Customers align based on their order of arrival and must wait their turn to be served (Dickson et al.). No preference exists for the frequency with which the patron uses the service, the quantity or magnitude of the serve they seek, or the urgency of the patron to continue with the rest of their plans for the day (Dickson et al.). The only factor that is taken into account in the FCFS line is the punctuality of the customer, which is the reason that the system appears fair (Dickson et al.). A number of factors contribute to the perception of and satisfaction with the queuing principle. These influences include, but are not limited to, clarity in the selection rules that govern the waiting process and the perceived fairness of the selection method (Dickson et al.). If either of these components are absent or considered inadequate by the client, individuals waiting in line are more susceptible to display high levels of dissatisfaction with their wait (Dickson et al.). The concept of the FCFS principle accounts for both of these components: the order of service is exactly the order of arrival, and the selection method only involves serving the next customer in line. Theoretically, the FCFS system is ideal and fair, but the practical restraint of capacity limitations tempers the potential effectiveness of the queuing method (Dickson et al.). The term capacity is used in two senses: the physical space in which patrons wait and the maximum number of clients that can be served at a given time. Capacity limitations will inhibit the success of *any* queuing method, but the FCFS system in particular does not sufficiently address the overcrowding that can occur during peak times (Dickson et al.). Regarding the number of clients that can be served, few adjustments can be made to account for rapid changes in queue length (Dickson et al.). In an environment with a constant influx of customers, FCFS lines should function well (Dickson et al.). On the other hand, many companies and businesses operate in dynamic environments, such as theme parks or malls, which feature variable levels of demand (Dickson et al.). Predictions can ensure changes in queue length do not occur unexpectedly, but variable demand for a service will result in fluctuations in line length that must be accounted for (Dickson et al.).

The primary issue with the FCFS system lies in the fact that the queuing principle lacks regulation outside of turning customers away (Dickson et al.). In effect, sporadically changing queue lengths caused by variable demand can only effectively be managed by expediting service as much as possible, not by managing the queue alone. Businesses can account for this deficiency by instituting a standard limitation in operational capacity for non-peak days, for example a check-out line that only uses a certain number of registers during unpopular times (Dickson et al.). The store can open more registers as the arrival rate increases, but once the service reaches capacity, nothing more can be done (Dickson et al.). No amount of additional staff can add capacity (Dickson et al.). Compounding upon this issue, the FCFS system also does not offer a resolution for the same type of overcrowding issues that were observed during the early years of Disneyland. The FCFS system depends upon a physical line of customers waiting to be served (Dickson et al.). When an excess number of customers is waiting to be served, the queue is overflown (Dickson et al.). Businesses must organize the queue so that the increasingly long line does not impede the operation of the service while still maintaining the original order of arrival of the customers (Nelson). The variable level of demand and influx of customers can result in unaccounted for and drastic changes in queue length, for which the FCFS system does not offer an effective solution.

An alternative queuing principle to review is the reservation system. Customers are permitted to request a time slot in which they are eligible to receive a service (Dickson et al.). Reservations can be made on the day of the intended service or before the date of anticipated service, regardless of how long in advance (Dickson et al.). Businesses have the freedom to control the influx of customers based on the number of reservations they permit for a provided time slot (Dickson et al.). In effect, management can ensure that the number of patrons arriving will always be matched to the capacity of the business (Dickson et al.). The reservation system results in the twofold benefit of providing customers a substantial amount of freedom in controlling the time in which they receive a service, and allowing businesses to shift demand by designating the eligible time slots in which a service can be received (Dickson et al.). While the reservation system can occasionally lead to unethical practices by businesses, for example airline companies that overbook their flights to ensure all seats are filled, the system largely allows businesses to match their capacity with the schedules of their customers (Dickson et al.). Similar to the FCFS system, the reservation system displays a number of flaws in addressing queue management. The reservation system does not offer a sufficient manner in which to address missed appointments (Dickson et al.). Customers cannot simply return later in the day without a second reservation, and businesses must navigate an already complicated schedule to accommodate the new appointment (Dickson et al.). In addition, businesses run the risk of alienating the customers who do not make early reservations (Dickson et al.). If a business can only offer a specific number of reservations in a day, customers who attempt to make reservations later in the day are blocked from receiving the service (Dickson et al.). If a business can offer an unlimited number of reservations, then the queuing process would succumb to the same issues as the FCFS queue in which regulation is lost (Dickson et al.). While the reservation system is largely beneficial for the freedom the system permits customers and businesses, the queuing principle does not offer sufficient flexibility in rescheduling appointments. Table 6 summarizes the general features of both queuing principles.

Table 6

	First-come, first-served	**Reservation**
Selection process	Order of arrival	Customer choice
Speed of service	As quickly as possible	At leisure of customer
Freedom of movement	Confined to line	Able to pursue other activities
Ease of return	Standby line always open	Requires additional reservation
Primary flaw	Lack of regulation	Lack of flexibility in rescheduling

Table 6: Major features of the first-come, first-served and reservation systems. Benefits and deficiencies of both queuing principles are presented (Dickson et al.).

Proposed Queuing Process

Both the first-come, first-served system and the reservation system appear to maintain unavoidable obstacles that inhibit a smooth queuing operation for both customers and businesses. Neither system is ineffective, or even close to ineffective for that matter, but an alternative method that combines elements of both principles should result in a more efficient method of queuing. Specifically, businesses operating in dynamic environments should attempt to recreate a FastPass-style queuing system in which the option of waiting in a virtual queue is offered in conjunction with retaining the possibility of waiting in a traditional queue. This proposition not only expands upon the successes of the FastPass system, but also accounts for the aforementioned disadvantages of the FCFS and reservation systems as a result of the fact that the proposed queuing method can be built upon the two principles.

By providing customers the option of choosing between waiting in a physical line and securing a position in a virtual queue, businesses should mirror the positive results of the FastPass system. As previously mentioned, the FastPass system succeeds due to the freedom of choice offered to guests in selecting the queuing option that allows for the most efficient use of time, which often ends up being the shortest option (Dickson et al.). This freedom results in the self-regulatory nature of the queuing system (Dickson et al.). If businesses implement a similar model, the same sense of freedom would be offered to the clientele as long as patrons were made aware of the length of the traditional queue. Specifically, customers would need to be provided current waits times, for example by means of a phone application, to ensure an informed decision is made. Furthermore, the proposed queuing method resolves many of the disadvantageous of the FastPass system, namely excessive prioritization of time and overscheduling. Creating an emphasis on timing and speed of service allows customers additional time to complete other errands or make additional purchases while they wait for the service (Dickson et al.). Unlike theme parks, the everyday world is not a contained environment with a limited number of activities; overcrowding would likely not occur in high-traffic areas because customers are free to move anywhere (Dickson et al.). The issue of overscheduling is not as easily resolved, but can still be addressed. As mentioned, customers require information regarding the status of both the standby queue and available reservation time slots in order to make an informed decision (Dickson et al.). Excessive overscheduling may effectively force customers without a reservation to wait in the traditional queue regardless of preference due to the fact that too many return times have been distributed. As a result, the integrity of the proposed system is lost. In distributing return times akin to the operation of the FastPass system, where businesses assign a time of service as opposed to permitting total freedom on behalf of the customer to choose, the overscheduling problem is alleviated.

The proposed queuing system is also built upon two of the major queuing principles already in existence, the first-come, first-served and reservation systems. A FastPass-style system retains the element of fairness associated with the FCFS principle, but accounts for the lack of regulation by introducing the virtual queue option. Similar to FastPasses, return times for services would be distributed based on a percentage of the total capacity of the business, which would ensure that the total influx of customers is regulated even if the traditional queue is not (Dickson et al.). Regarding the principles of a reservation system, the proposed queuing method offers considerable freedom to businesses and customers in allowing patrons to pursue other activities while in a virtual line. The lack of flexibility in rescheduling missed return windows is resolved by maintaining a traditional queue that is always accessible. In general, the proposed combination of physical and virtual queues offers the same self-regulatory nature as in the FastPass system, which should expedite wait times and offer customers more free time. Beyond that, the system is governed by a combination of two preexisting queuing disciplines, which implies that the method can be implemented merely by offering customers the choice to wait in one line or the other.

Potential Applications and Limitations

While a number of services could potentially benefit from a FastPass-style queuing system, a call center in particular appears to be an advantageous application of the method. A 2014 case study was performed to analyze the effectiveness of implementing a call-back option for a multi-server call center (Dudin et al.). Businesses use call centers to receive client requests as well as serve customers over the phone (Dudin et al.). A primary concern of companies is to offer effective service in fielding a large number of calls while minimizing the number of losses attributed to large durations of time spent waiting to connect to a representative (Dudin et al.). The problem can be amended by instituting a call-back option in which customers who prefer not to wait for an available operator can choose to be contacted directly by the representative at a later time (Dudin et al.). Similar to the FastPass system, clients would be alerted of the estimated wait for an operator, which corresponds to the standby line, and may either wait in line or receive the call-back time, which corresponds to the FastPass option. This option helps to minimize the likelihood of customers hanging up out of frustration due to a long wait while also ensuring the continued effectiveness in representatives serving the customers who choose to wait (Dudin et al.).

A mathematical model was developed to describe this system according to the Markovian arrival process, which in simplest form corresponds to a customer arrival rate that is modeled by a Poisson distribution (Dudin et al.). When a server (operator) is available, customers have three options: to leave the system without service, to become a real customer and wait in line, or to become a virtual customer and receive a call-back time (Dudin et al.). Virtual customers are served when a free server is available, which occurs when real customers waiting in the traditional queue have been served (Dudin et al.). In effect, the system operates under a combination of the FCFS and reservation principles. A certain threshold is assumed to exist in which no further customers may enter the physical line; customers may either elect to pursue the virtual option or not receive the service (Dudin et al.). A number of other factors are also considered in the model: the probability of a virtual customer not answering the return call, the likelihood of a real customer leaving the system due to impatience, and the necessity of deeming a server filled when dialing a virtual customer (Dudin et al.). In order to treat the processing time of all customers in a unified manner independent of customer type, a generalized phase-type distribution is considered (Dudin et al.).

The advantage of such a model allows businesses to calculate a number of factors such as the average number of real and virtual customers waiting to be served, the loss probabilities of real customers either leaving the service or pursuing the virtual option, and the average wait times for both real and virtual customers (Dudin et al.). All of these factors can be measured as a function of the number of servers present, which ensures that the optimal number of operators are available to minimize cost and maximize efficiency (Dudin et al.). Fig. 3 displays two representative plots of the model: the likelihood of a real customer pursuing the virtual route and the average wait time for a real customer, both as a function of number of operators (Dudin et al.). The loss probability and average wait time are plotted for different coefficients of correlation, which accounts for the linear relationship of sequential arrivals and the subsequent quality of service offered to customers (Dudin et al.). In short, a coefficient of correlation of zero corresponds to a Poisson distribution in which there is no linear relationship between successive arrivals. Table 7 offers an intuitive display of the effect on loss probability and wait times based on a given coefficient of correlation for arrivals and the corresponding fixed, optimal number of operators (Dudin et al.).

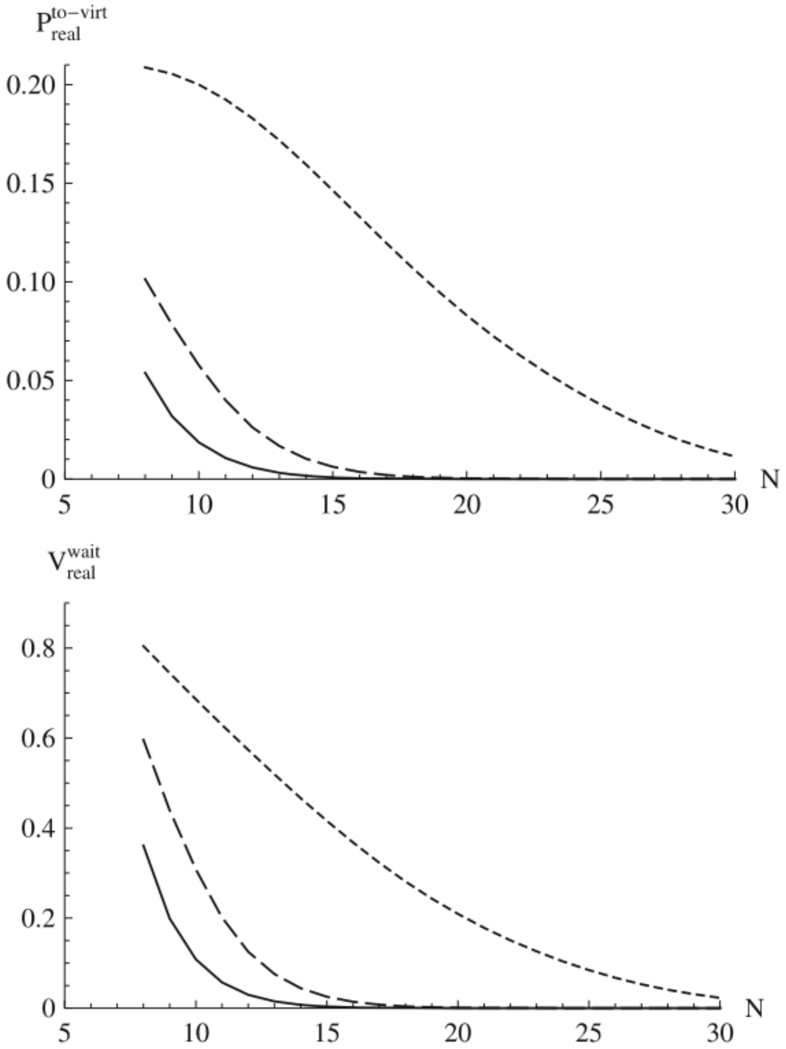

Figure 3: Two sample charts derived from the mathematical model describing a call-back option for a customer call center. The probability of a real customer exiting the queue in favor of receiving a call-back time is presented as a function of the number of operators (above). The average wait time of a real customer is also presented as a function of the number of operators (below) (Dudin et al.).

Table 7

Coefficient of Correlation	**Number of Operators**	**Loss Probability**	**Virtual Wait**	**Real Wait**
0	11	0.0427	1.3	0.057
0.2	13	0.0425	1.7	0.052
0.4	27	0.0315	2.3	0.076

Table 7: Loss probability and wait times for real and virtual customers determined by the fixed, optimal number of operators available for a given arrival distribution. The number of servers is highly sensitive to the coefficient of correlation (Cope et al.).

The number of operators is sensitive to the coefficient of correlation of the arrivals (Dudin et al.). For example, employing 11 operators to serve an arrival flow with a coefficient of correlation of 0.4 would result in a loss probability of nearly 20% and average wait time increase to 32 and 0.987 for virtual and real customers, respectively (Dudin et al.). The developed model not only describes an improvement in the waiting process, but also provides a method of optimizing the service (Dudin et al.). This case study does not present the only viable implementation of a FastPass-style queuing system, but the analysis should serve to demonstrate the potential successes and applications of such a line structure.

Other possible applications of the proposed queuing system include: resort activities, walk-in clinics, check-out lines, airport security lines, and equipment usage at gyms; however, not every service industry can benefit from such an implementation. For example, doctor appointments often require planning and preparation to ensure an adequate health evaluation, which cannot be accomplished by waiting on a standby line or by securing a spot in a virtual queue the day of a visit. Even further, emergency rooms do not exclusively operate under the same principles that govern the FCFS and reservation systems; for example, injury severity is considered when determining service order. As a result, doctor visits and hospital stays would likely not receive as much benefit from a modified queuing system. In addition, sporting events or theater performances are another example of a service that would likely not benefit from a modification in the queuing method. Each seat in a venue has a value specified by the location, which takes into account section, row, and level. While all customers attend the same event, the anticipated experience differs based on the amount of money spent to secure the position. Only one event takes place at a time, which implies that any capacity *limitations* in the service are in fact capacity *restrictions*. No amount of queue management can modify the maximum number of patrons that can be in attendance for a given event.

Illuminated by these examples, two features may restrict the implementation of the proposed queuing method for a service. Specifically, if a significant source of preference for service order exists beyond that which governs the first-come, first-served principle, for example injury severity or ticket price, then the proposed queuing system would likely not be as successful. If the service demands a specific time and location as well as maintains a fixed capacity, the success of the queuing method would also likely diminish. The applicability and anticipated success of the proposed queuing revisions are contingent on the fact that the waiting process was already, or could have been, successfully operated by the principles of the FCFS system and/or the reservation system.

Concluding Remarks

The necessity of queuing will likely never cease to exist as long as there is demand for a given service. Therefore, pursuing new ways to improve the waiting process shall remain relevant and important to explore, especially due to the increasing desire of consumers to manage their free time as efficiently as possible. The proposed queuing model is framed as an adaptation of the Walt Disney Company's FastPass system, and the basis of operation is derived from two commonly-enacted queuing principles, namely the first-come, first-served system and the reservation system. The proposed queuing modification functions more as a reorganization of the common approach to queuing theory than as a complete overhaul of the standard methodology. While a number of limitations may impede the complete success of the implementation of the proposed queuing method, an application of the Disney FastPass system to everyday experiences would appear advantageous to both consumers and service providers. The world of theme parks and the world beyond them are often seen as distinct and unrelated; an analysis of the current state of queuing theory and a review of the history and development of theme park queuing systems should serve to demonstrate the potential for an expansion of the intermingling of theory and technology between the two worlds.

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