Super Bathrooms

Team 486

Abstract

QuickPass machines are a system of regulating popular rides at an amusement park designed to reduce the amount of time that is spent waiting in line. We are asked to develop a scheme to administer the QuickPass system at a given amusement park in order to increase the overall enjoyment experienced by visitors. We are also required to have our system avoid certain anomalies reported by previous users of the system. In this paper, we derive a theoretical model for analyzing the enjoyment of visitors at a theme park based on principles of economic equilibrium and game theory.

Viewing the problem from a game theoretical perspective, we are able to represent enjoyment as a function of two factors: the total time spent waiting in line and the delay incurred by having to wait for a QuickPass return time to arrive. We perform a theoretical test of this system and find it to be robust.

We use our model to evaluate three classes of schemes:

- Schemes that vary the time interval at which a QuickPass machine asks a visitor to return to the ride,
- Schemes that vary the rates at which people are admitted onto rides from the regular line and the line designated for QuickPass ticket holders,
- And arbitrary schemes that vary the delay time of a QuickPass ticket holder's return to the ride. The model thus allows us to determine which system meets our criteria of maximal enjoyment by comparing the different values of enjoyment a set of schemes yield.

We derive theoretical mathematical proofs to show that the case in which the non-QuickPass line has been eliminated is the best possible system with respect to visitor enjoyment.

1 Goals

We have two objectives in developing a system to assess the quality of a QuickPass scheme:

- To measure the total enjoyment experienced by visitors to the amusement park under the scheme.

- To ensure that the scheme avoids the anomalies reported by users of the current system.

2 Terminology

The following are some key words and concepts that we rely heavily upon in the paper.

Scheme: A *scheme* is a method of administering the QuickPass system for rides at a park, including the method for assigning return times to ticket holders.
Lines: There are three different types of lines:

- **Regular line:** The *regular line* for a ride, P_r, is a queue of visitors that operates independently of the QuickPass system.
- **Virtual QuickPass line:** The *virtual QuickPass line,* Q, is a virtual queue counting the visitors with outstanding QuickPass tickets in the order that they pulled the tickets.
- **Physical QuickPass line:** The *physical QuickPass line,* P_q, is a physical queue in which a visitor stands from the time that they turn in their QuickPass ticket upon returning to a ride until the time that they exit at the end of the ride.

Rate: The *rate* of a ride is the average number of people per minute who can take that ride.

Wait: The *wait,* denoted by W, is the length of time between the initial entry at the beginning of a line to the final exit at the end of ride.

Park Attendance: The *park attendance* , denoted A_t, is the number of people in the amusement park at any time t.

3 Assumptions

- **Every visitor in the park acts independently to maximize his or her own enjoyment.** Regardless of the additional benefit that might be gained, the large number of visitors makes cooperation impossible.
- **At the amusement park there are two types of activities:**
  (A) **Popular rides,** which are more desirable than other activities and implement the QuickPass system in order to alleviate the massive lines and physical wait times.
  (B) **Alternative attractions,**which include unmetered rides and free time within the park. These are less desirable than popular rides and do not have QuickPass machines.

- **Visitors should always take a QuickPass ticket.** This is a consequence of our first assumption that each visitor acts to maximize their enjoyment; as the visitor is not obligated to arrive during the QuickPass window, the action of taking a QuickPass ticket can only increase their range of available options and can only serve to potentially increase their enjoyment.
- **Visitors get a fixed level of benefit per minute by pursuing alternative attractions.** Because the number of alternative attractions is large and because many of them naturally require little or no waiting time, visitors will be able to accrue the same amount of benefit from this collection of attractions at all times.
- **The motion of lines can be approximated as continuous.** The motion of lines is continuous in the limit as ride duration becomes very small. We will show later in this paper that the effects of this assumption on the results of our scheme evaluations are minimal.

4 Model Development

4.1 Overview of Approach

¿From a game-theoretical perspective, the QuickPass system is essentially a regulatory mechanism used to reduce inefficiencies caused by lack of cooperation. In this section we work to understand the behavior of visitors at the park in an equilibrium in order to quantify the enjoyment they experience under different QuickPass schemes. We first build the model for a baseline case that does not include a QuickPass system; we then expand the model to account for the presence of a QuickPass line.

4.2 Equilibrium Theory

Equilibrium theory states that an unregulated economic system will naturally gravitate towards the state where the cost of a service is directly proportional to the amount of utility that one experiences from it. We apply this theory to the problem by representing the amusement park as an economic system with wait time as cost and enjoyment as utility.

4.3 Need Only Consider One Popular Ride (Part 1)

We treat only a simple case where there is one ride with a set utility gain. This simplification can be made because generalizations to a park with n different rides will exhibit the same behavior in the equilibrium model as one ride with an arbitrary utility.

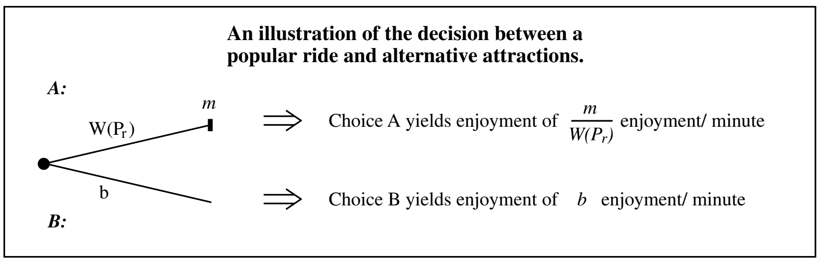
4.4 An Unregulated Amusement Park

In order to evaluate how to quantify enjoyment at a theme park, we examine the behavior of persons at an amusement park *without a QuickPass system* in place.

4.4.1 Determination of Value Based on Choice

When assessing their next action in the unregulated amusement park, visitors have two choices:

- Choice A: Wait in line and eventually take a popular ride.
- Choice B: Do not wait in line and instead enjoy alternative attractions.



An illustration of the decision between a popular ride and alternative attractions.

There will be a certain benefit obtained by following each of these strategies. The benefit per minute from Choice A will equal the benefit obtained by riding a popular ride, denoted here by m, divided by the time it takes to wait for that ride, i.e.

$$\frac{enjoyment}{minute} = \frac{m}{W(P_r)}.$$

The enjoyment per minute of choice B is fixed at some value b. Visitors will choose whichever option yields a higher utility, so they will choose the option that provides the highest benefit per minute.

Comparing $\frac{m}{W(P_r)}$ and b, as long as b and m are positive numbers we will find that there is a threshold value for $W(P_r)$ such that the two values are equal. Call this value $\max_{wait}$. Thus, we get the equality:

$$\frac{m}{\max_{wait}} = b$$

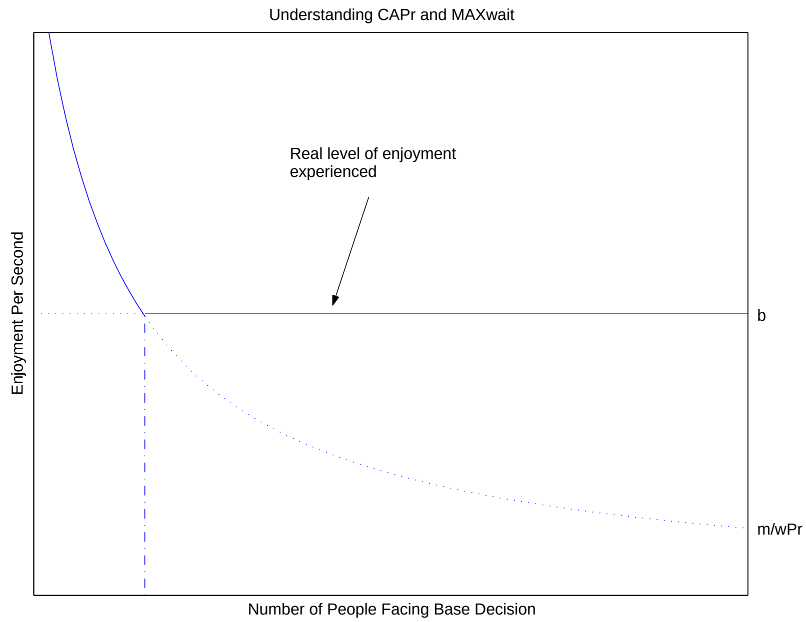
We find that for $W(P_r) < \max_{wait}$ it is the case that the person will choose Choice A. And correspondingly, for $WP_r \geq \max_{wait}$ the person will choose Choice B. Hence, max_{wait} is the maximum amount of time someone is willing to wait to ride a popular ride.

Before continuing it is important to define the number associated to the maximum wait time, the line capacity: $cap_r = \max_{wait} \cdot rate_r$.

4.4.2 Calculating Enjoyment in the Unregulated Amusement Park: The Baseline Case

Each person in the amusement park will face the same choice. Thus, we may define the average unregulated enjoyment piecewise to be:

$$E^0(A_t) = \left\{ \begin{array}{cc} \left(\frac{m \cdot rate_r}{A_t}\right) & , \text{when} A_t < cap_r \\ b & , \text{when} A_t \geq cap_r \end{array} \right\} \tag{1}$$



4.5 Need Only Consider One Popular Ride (Part 2)

Now that we have the proper notation defined, we can easily see why this is true. Consider rides $1, \cdots, n$ each with their own enjoyment $m_1 \cdots m_n$. These rides will fall into an equilibrium with wait times $W(P_{r_1}), \cdots, W(P_{r_n})$ with the property that:

$$\frac{m_1}{W(P_{r_1})} = \quad \cdots \quad = \frac{m_n}{W(P_{r_n})}$$

Therefore, these rides act as one.

4.6 Calculating Enjoyment in a Regular QuickPass-Integrated System

Having established a method for quantifying enjoyment in a simple system, we now use a similar approach to quantify enjoyment in the more complex system in which QuickPass lines coexist with regular lines. This quantification will provide us with a criterion by which we may evaluate competing QuickPass schemes. In doing this, we use the same general assumptions as before. We note first that:

4.6.1 Different Lines, Different Rates

In a regular QuickPass-integrated system there are two ways that a visitor may board a popular ride. They may wait in the regular line or they may take a QuickPass ticket and return at a later time to wait in the physical QuickPass line. As entry from these lines is most likely overseen by human attendants, it is unreasonable to expect that these rates will be anything but fixed throughout the day. These rates can be expressed formally by $rate_r$ for the regular line and $rate_q$ for the QuickPass line. So as to ensure that the ride runs full each time, these rates have the property:

$$rate_r + rate_q = rate$$

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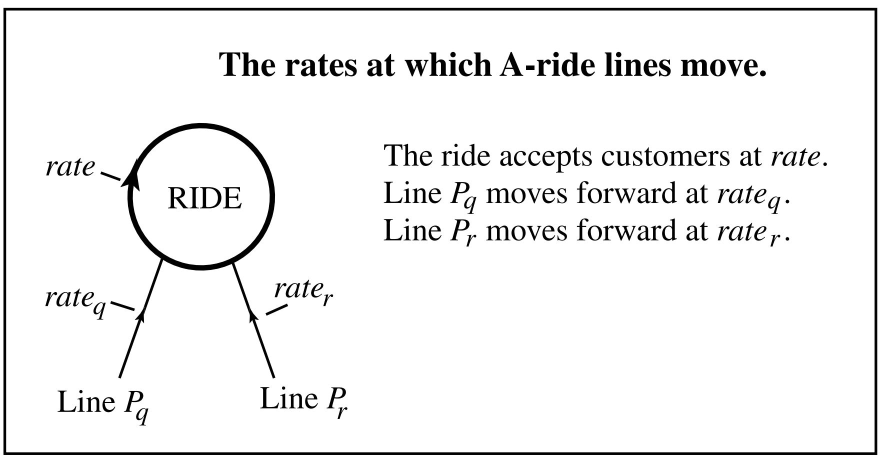


4.6.2 The Virtual QuickPass Wait Time

$W(Q)$ is the total time that a QuickPass ticket holder must wait from the time s/he pulls the ticket to the time s/he boards the ride. $W(P_q)$ is the amount of time that the ticket holder must wait in the physical QuickPass line. The length of time that the QuickPass holder spends before getting in the physical QuickPass line is essentially *free time* and will be denoted by F. The following important relationships are thus implied:

$$W(Q) = W(P_q) + F$$

and

$$W(Q) = \frac{A_t}{rate_q} + \epsilon,$$

where ϵ is an error term that comes from uncertainties in a variety of factors that are discussed in more detail in Section 8.1.

4.6.3 Enjoyment in the Regular QuickPass-Integrated System

The enjoyment a visitor accrues from his/her experience in the park comes from the enjoyment obtained using the QuickPass system to take rides on popular rides and the enjoyment obtained during the time not spent in the physical QuickPass line. Because they may only hold one QuickPass ticket, during their free time visitors face the same limited Baseline choice as before:

- Choice A: Wait in line and eventually take an A-ride
- Choice B: Do not wait in line and enjoy alternative B-level attractions.

We demonstrated in the Baseline Case that this pair of choices yields an enjoyment function of E^0 defined earlier. The only difference in this case is that the argument of E^0 is the number of people with free time, $NF = F \cdot rate_q$ instead of the full park attendance.

Thus we find that in the time from when a visitor first pulls a ticket to the time they can pull another, they accrue enjoyment from two sources. The first comes from the benefit accrued from the popular ride itself as a result of the QuickPass system:

$$\text{Enjoyment}_{part1} = \frac{m}{W(Q)}$$

The second comes from the benefit accrued during free time:

$$\text{Enjoyment}_{part2} = \frac{F \cdot E^0(NF)}{W(Q)}$$

Adding these two sources of enjoyment together yields the definition for total enjoyment per minute of the regular QuickPass-integrated system:

$$E^q(A_t) = \frac{F \cdot E^0(NF) + m}{W(Q)} \tag{2}$$

4.6.4 The Special Case

It should be noted that $q = 1$ represents a special case when there are no regular lines and so, when not waiting in the physical QuickPass line, one has only the option of taking type B rides. This special case is important as later on in the paper (Theorem 1) we prove that it yields maximum enjoyment with respect to the q variable.

5 Schemes

We have now developed criteria for evaluating the quality of a scheme in terms of the enjoyment experienced by visitors to the park. We now consider three general classes of schemes that can be generated and tested within this model. In Section 6, we will evaluate each of these schemes according to the framework we have developed above.

At time t_0, a visitor who recieves a QuickPass ticket will be asked to return within the time interval $[t_0 + h, t_0 + h + l]$ for some h, the window delay time, and some l, the window length.

5.1 Window Length

In creating an effective QuickPass ticket-issuing scheme it is essential to consider the significance of the length of the window of time allotted to the QuickPass ticket holder within which they may return to the ride. We may try to vary the window length, l, and view any changes in enjoyment.

5.2 Window Starting Time and Arbitrary Schemes

Just as we may vary window length, we may also vary the time that it starts. In addition, we may combine variations in window length and window timing to duplicate any proposed scheme.

5.3 Varying Relative Admission Rates

Within this class of schemes, the relative rates of admission, $rate_r$ and $rate_q$, from the regular line and physical QuickPass line are adjusted through varying the parameter q. At any given time under this scheme, people who take a QuickPass ticket at a given time t are asked to return at time $t + W(Q)/rate_q$. We will also consider two special cases of this scheme. In the first, we set $rate_r = rate$, eliminating the QuickPass system entirely. In the second, we set $rate_q = rate$, effectively prohibiting the physical line from forming. This case will be shown to be optimal.

6 Evaluation of Schemes

6.1 Window Lengths Do Not Matter If They Stay Reasonable

In this section we work to determine what the best window length should be. We find that due to the interplay of uncertainty and other variables, there will be no one optimal length. Instead, we can only recommend that the window length be chosen from a range of reasonable lengths.

6.1.1 The Distribution of Arrival Times in a Window

We treat a visitor's arrival time to the QuickPass (P_q) line as a random variable following independent identical probability distributions with the property that the probability that a visitor will arrive outside the window interval will be zero.

6.1.2 No No-Shows.

We assume that everybody will appear during their assigned window time. We discuss the error associated with this assumption in Section 8.2.

6.1.3 Proof That Length Does Not Matter

The exact distributions of the arrival times and thus the window lengths allotted to QuickPass users are easily shown to be irrelevant:

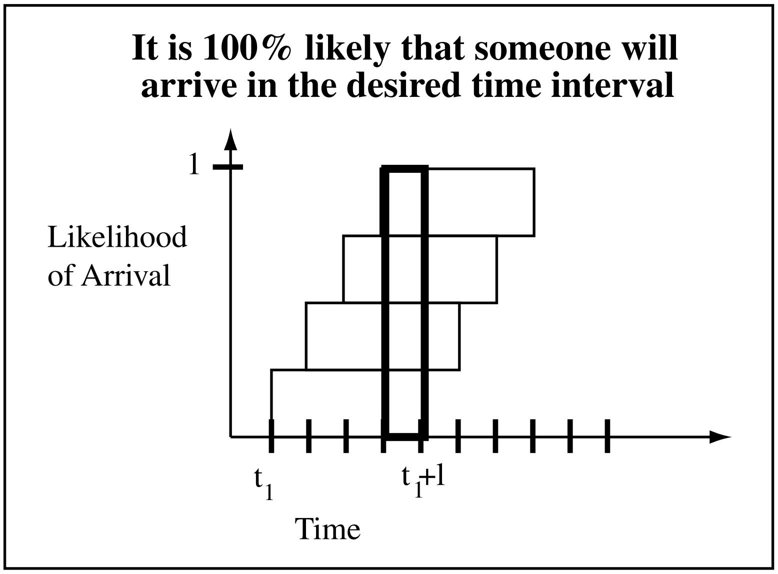
Assume for now that the event of a person showing up at a specific given instant within their allotted window timeframe is a uniformly distributed random variable; we refer to this event as X. The scheme suggests uniformity because we cannot predict the trends of random visitor behavior on a daily basis.

The probability density function of X, whose window of return starts at time t_1 and ends at $t_1 + l$ is shown below in Figure 4. When a continuum of people is added to the timeline or plot, we see that the sum of their density functions becomes constant over time, except for the start and end points of the timeline, which implies that it is only possible for a fixed number of people to show up within any given timeframe. This effectively creates one large uniform distribution blended together, where people are continuously entering the system and arriving to the P_q line at near uniform rates.

In order to control the number of people expected to enter the P_q line within the window length l, the spacing between allotted return times should be separated by at least $\frac{l}{n}$.

This reasoning is easily generalized to other probability distributions, which makes this statement even stronger.

Therefore, under the assumption that there are no no-shows, the exact length of the suggested window of return, assuming a reasonable timeframe, is irrelevant.



6.1.4 Why Extreme Lengths are No Good

There are two extremes for the lengths of the window:

- **The window could be too short:** When this happens, it is likely that people will forget or not be able to make it in time to their window. This leads to people having to wait in line again from the very beginning.
- **The window could be too long:** As the window length grows, the standard deviation will continue to grow as well. This in turn will cause the distribution of arrivals to become more chaotic and will make it more difficult to optimize the system.

There is no rigorous definition for an "extreme window length." We suggest that the amusement park set the length of a window to be some reasonable amount of time, between 20 and 60 minutes.

6.2 Ensure That Average Window Arrival Time Is $W(Q)$

Suppose that we have a QuickPass scheme that returns a ticket with mean return time $t_0 + h$. We may compare this return time with the time in which people could maximally be packed into the ride from the QP line: $t_0 + W(Q)$. In comparing the two schemes, there are two possibilities:

Case 1: $h > W(Q)$.

But, when this is the case, we can expect that the ride will be leaving during the $[t_0, t_0+h]$ time period with only $\frac{W(Q)}{h} < 1$ of the ride filled. This inefficiency cannot be resolved.

Case 2: $h \leq W(Q)$.

In this case, free time, F, is artificially limited. But, as we will see in Theorem 2 this is optimal only when $F = W(Q)$.

Theorem 1 *Given any $q \in [0, 1]$ with q indicating the QP rate proportion for $rate_q$, the optimal scheme will work to maximize F, the amount of free time available to the customer, which in turn is done by minimizing $W(P_q)$.*

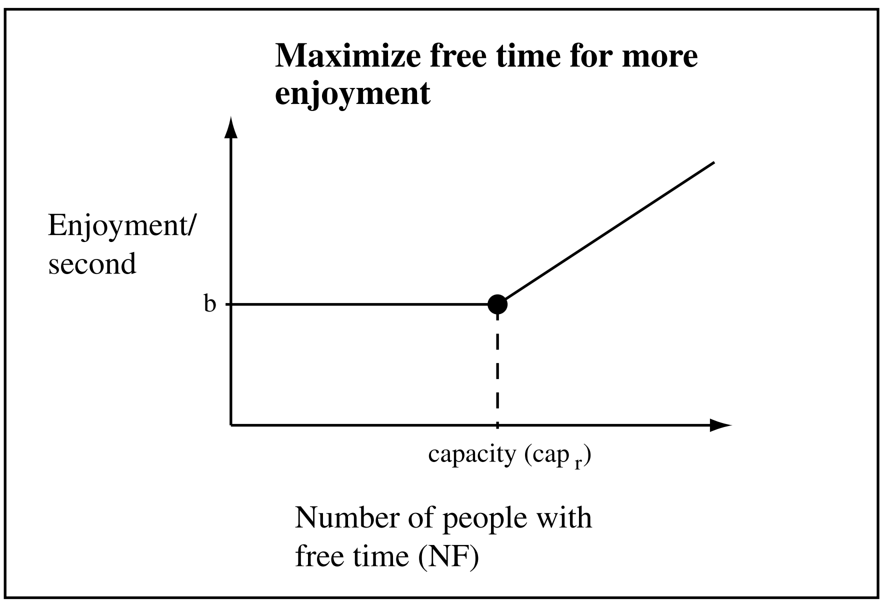
Proof: By definition of E^q:

$$E^q(A_t) = \frac{F \cdot E^0(NF) + m}{W(Q)} = \frac{NF \cdot E^0(NF)}{A_t} + \frac{m}{W(Q)}$$

Consider for now only $NF \cdot E^0(NF)$. We may look at $E^q(A_t)$ as a function with respect to the NF variable. We consider that:

$$\begin{aligned} NF \cdot E^0(A_t) \quad &= m \cdot rate_r \quad && \text{for} NF < cap_r \\ &= NF \cdot b \quad && \text{for} NF \geq cap_r \end{aligned}$$

And note that $NF \cdot b \geq cap_r \cdot b = m \cdot rate_r$. Thus we may maximize the enjoyment $E^q(A_t)$ with respect to NF by simply maximizing NF. Figure 5 below demonstrates how this works. ∇



We now know that we want to maximize the amount of free time available to the customer. This free time is bounded by $W(Q)$. Equivalently, the scheme E^q yields maximum enjoyment when the wait time $W(P_q)$ is minimized.

Thus, in order to optimize schemes, we must minimize $W(P_q)$, the wait time in the physical QuickPass line.

6.3 The Special Case Is Optimal With Respect To Admission Rates

In this section we evaluate all schemes that set a fixed rate between the regular and QuickPass lines and find that, with all things equal, higher rates for the QuickPass (in exchange for lower regular rates) yield higher average levels of enjoyment. This assertion is essentially the content of the following Theorem.

Theorem 2 *$E^q(A_t) > E^p(A_t)$ when $q > p$.*

Proof: By definition of E^q in Equation (2):

$$E^q(A_t) = \frac{F \cdot E^0(NF) + m}{W(Q)} = \frac{NF \cdot E^0(NF)}{A_t} + \frac{m \cdot rate_q}{A_t}$$

Consider two cases.

Case 1: $NF < cap_r$. Then:

$$E^0(NF) = \frac{m \cdot rate_r}{NF}$$

So we see that:

$$E^q(A_t) = \frac{NF \cdot \left(\frac{m \cdot rate_r}{NF}\right)}{A_t} + \frac{m \cdot rate_q}{A_t} = \frac{m \cdot rate_r}{A_t} + \frac{m \cdot rate_q}{A_t}$$

Because $rate_r + rate_q = rate$ we see that the above simplifies to $E^q(A_t) = \frac{m}{W(Q)}$.

Case 2: $NF \geq cap_r$.

Then $E^0(NF) = b$. So:

$$E^q(A_t) = \frac{NF \cdot b}{A_t} + \frac{m \cdot rate_q}{A_t} = \frac{(NF - cap_r) \cdot b}{A_t} + \frac{cap_r \cdot b}{A_t} + \frac{m \cdot rate_q}{A_t}$$

Note that $cap_r = max_{wait} \cdot rate_r$ and that $b = \frac{m}{max_{wait}}$ so that $cap_r \cdot b = m \cdot rate_r$. Substituting this in, we see that:

$$E^q(A_t) = \frac{(NF - cap_r) \cdot b}{A_t} + \frac{m \cdot rate_r}{A_t} + \frac{m \cdot rate_q}{A_t}$$

$$= \frac{(NF - cap_r) \cdot b}{A_t} + \frac{m}{W(Q)}$$

So, we may look at E^q as a function of r. In order to maximize E^q with relation to r one only needs to minimize cap_r. But $cap_r = \max wait \cdot rate_r$, which means that one need only minimize $rate_r$; this is equivalent to maximizing $rate_q$. Thus:

$E^q(A_t) > E^p(A_t)$ when $q > p$. ∇

As an immediate result of this, we find that $E^1(A_t) \geq E^q(A_t)$, for all $q \in [0, 1]$. In other words, E^1 is optimal with respect to q.

7 Results

Based on the preceding theoretical proofs, we come to the following conclusion:

* Schemes which vary the relative rates of admission between the regular line and the physical quickpass line can do no better than the special case in which we set the rate of the QuickPass line to q=1 and the regular line to 0, eliminating the regular queue.

* Schemes which vary window length published on the QuickPass ticket cannot do any better than the q=1 case.

* Schemes which vary the arrival time issued by a fixed amount cannot perform any better than the q=1 case.

We therefore make the following recommendations for administering a QuickPass system:

·Remove the option for regular lines at popular lines and only allow the QuickPass system ·If deinstituting regular lines is not feasible, the scheme that minimizes overall wait time will be the one that maximizes enjoyment.

8 Model Accuracy and Suggestions for Future Expansion

We made the assumption that the QuickPass system can be made to run at near zero wait at all times; however, in reality, wait time will vary as a consequence of a number of factors. One group of these inaccuracies is due to the uncertainty that results from dealing with things that are impossible to quantify. The other group of these inaccuracies is due to problems in our assumptions of continuity, focused around the area in which the rides are continually departing. We gain an understanding of the uncertainties through ϵ. The lack of continuity is better understood in looking more closely at the ride departures. We analyze these two groups of factors in the following two sections.

8.1 The error, ϵ

In our work above, we have expressed the error in the Virtual QuickPass wait time as ϵ. In this, ϵ is composed of many factors, some of which include:

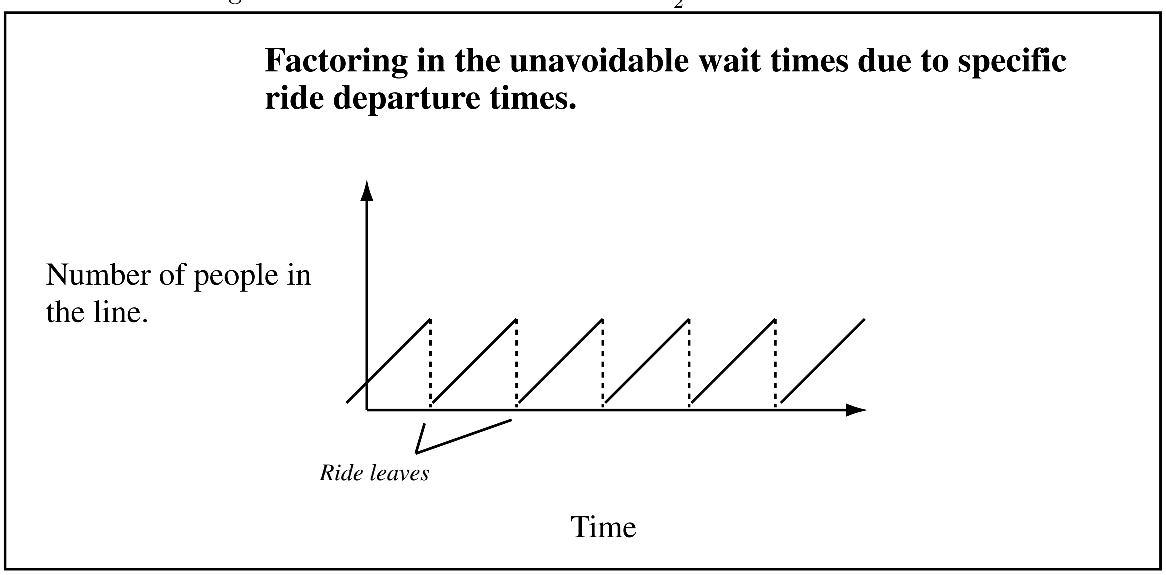
- Variations in exact ride departure time.

- Variations in the arrival time of people.
- The propensity for people to forget about their window.

We would have liked to explore these issues in more depth, but time constraints force us to account for these unknowns by adding an error term.

8.2 Concessions for the lack of continuity in ride departures

We roughly expect the actual wait time on even the best QuickPass schemes to behave according to the fact that lines are not truly continuous, but discrete according to the ride duration. Visitors arriving throughout a window will have to wait, at most, for the extent of the ride duration for the next car to leave. We find that the average unavoidable wait time is the $\frac{rideduration}{2}$



8.3 Minor difficulties with discrete ride departure times

Due to the uncertainty and the lack of true continuity, it will be impossible to perfectly maintain zero wait time in the physical QuickPass line. The fluctuations occur in two directions.

Sometimes the line will slow down and people will begin to have to wait in the physical QuickPass line. this is to be expected and does not cause great problems because these line lengths stay low and also the alternative is frequently to wait in either the regular line or to get only a very small amount of enjoyment through alternative rides.

Other times the line will move too quickly and the rate at which people are flowing into the line will be less than the rate at which they are entering the ride. This scenario opens the possibility for the ride leaving with less than a full load of passengers. While the line moving too slow does not cause serious problems, the line moving too quickly will cause inefficiencies that cannot be recovered. This is a problem.

8.4 Consider Implementing a "Spillover" Line

A possible solution this problem of not having enough people for the ride would be to introduce a new type of a line that only moves forward when the physical QuickPass line moves too quickly. We will call this type of line a "spillover line." While we do not have the time to fully evaluate the "spillover line," it does seem (in theory at least) that the "spillover line" would eliminate the inefficiencies outlined above.

9 Strengths

- The model avoids the specified set of complaints intrinsically by maintaining and enforcing the virtual queue of QuickPass holders.
- The model establishes a valid criteria for determining which types of plans will work and is able to make a definitive judgment of scheme superiority that is not dependent on the specific window lengths or rates of a specific scheme.
- It is robust with respect to variation in parameters. In particular, the exact enjoyment experienced on a given popular ride can take on any positive value without affecting the validity of our results.
- The model does not require additional information to be provided to the QuickPass machines outside of park attendance.

10 Weaknesses

- In certain amusement parks, the assumption about b being constant may begin to cause problems. This will occur if the difference between the QuickPass and the non-QuickPass rides is not large as it will be more likely that significant lines will form for the alternative attractions, lessening enjoyment. However, the general trend is that the b number will decrease more slowly than the value $\frac{m}{WP_q}$ and so the results of this model still are likely to hold true.
- The assumptions that the visitors preferences may form an average and that everybody will rationally maximize their enjoyment does not allow for diversity and randomness that might occur. As a result the model makes the situation appear to be more smooth than it really is. While this is

partially accounted for with the error term ϵ, it is also an inescapable byproduct of the macroeconomic equilibrium perspective that was adopted for the model.

It may be possible to extend the fact that window length variation and window time variation are irrelevant to window length to establish that the q = 1 case is as good as any scheme can possibly get; this constitutes worthy grounds for future exploration if we had more time.

11 References

Ross, Sheldon M. 2000. Introduction to Probability and Statistics for Engineers and Scientists. San Francisco: Harcourt Press.

12 Nontechnical Summary

9 February 2004 FROM: 486 Consulting, Super Bathrooms Department TO: FunPark, Inc. Executive Board RE: Executive Summary

We are pleased to present our recommendations for administering the QuickPass system at FunPark. Economic theory dictates most other aspects of running your business, so we present a method under which you can apply the same rules to measuring the efficiency of any given queuing system.

We developed a way to measure how much people are enjoying FunPark using economic theory that treats the experience of riding rides as a consumer product and the amount of time spent waiting for a ride as the price paid for that product. The system then gravitates to an equilibrium where people are acting to get the best bang for their buck in this case, thrill for their second in a quantifiable and measurable way.

Competing consultants may have brought schemes before your attention. Some schemes modify the rates at which users flow through regular lines versus lines designated for QuickPass ticket holders. We have succinctly proved that because the behavior of the two lines are unrelated, schemes that try to vary the relative rates can do no better than a scheme that bans normal lines and only allows QuickPass lines. Other schemes may attempt to modify the time the QuickPass system asks visitors to return to the ride, but we show that such changes will have little or no bearing on the resulting enjoyment. Enclosed in our report is a thorough analysis of what each of these schemes can do and the results of our analysis of each one. We found that out of these, only a scheme implementing QuickPass lines by themselves was most likely to maximize enjoyment. We have enclosed formal mathematical proofs of these relationships in our final report.

As an added bonus that you will find appealing, our criteria for measuring the quality of a given scheme depends on maximizing the number of people who have free time. This free time they are likely to spend at alternative revenuegenerating attractions throughout the park such as restaurants and carnival games.

Our final recommendations are as follows:

- Remove the option for regular lines at popular rides wherever possible
- If de-instituting regular lines is simply not feasible for reasons unrelated to overall enjoyment gain, attempt to minimize the size of the physical queue at all times and maximize the number of persons in the park with free time.
- Institute a secondary overflow line to account for inherent unpredictability in the QuickPass queue.