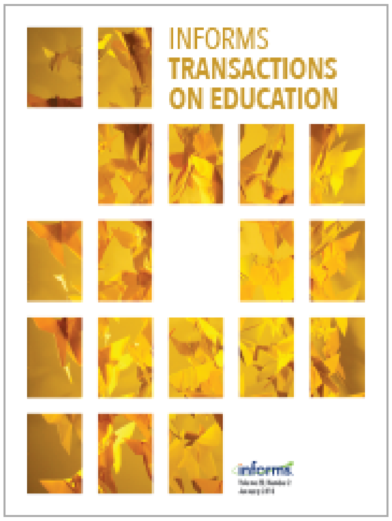

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Case

Potty Parity: Stadium Restroom Design

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Introduction

Carlos Villalpando, the stadium operations manager at the Rotman Football Stadium in Toronto, faced an overwhelming wave of complaints following the Toronto Warriors versus Alberta Bisons match in September 2023. The game, filled with electric energy, saw the Toronto Warriors win 24 to 14. However, despite the excitement, many attendees had mixed experiences, particularly regarding restroom facilities.

Issue Faced

For certain female attendees and members of the LGBTQ+ community, the match's excitement was overshadowed by a frustrating and disappointing experience. Overcrowding in restrooms led to prolonged wait times, causing significant discomfort and inconvenience, particularly for women. Mrs. Kimberly Powell endured a wait exceeding 30 minutes to use the restroom, which adversely affected her health, leading to bladder and kidney issues. Similarly, Federica, a devoted spectator, developed hemorrhoids because of the prolonged wait for restroom facilities. This ordeal evoked memories of her friend Claire's experience at a Broadway show in New York in November 2019, during which Claire encountered an unreasonable wait time during the 15-minute intermission. Claire forewent restroom use to avoid missing the performance, resulting in considerable stress. Mia, a transgender woman, encountered difficulties accessing designated women's and men's restrooms and abstained from using a restroom throughout the game, leading to severe anxiety.

Public Reaction and Management's Response

Disgruntled fans, primarily women and members of the LGBTQ+ community, expressed frustration through various channels, demanding compensation and calling for change. Despite Carlos's track record of providing excellent fan experiences, the sheer volume of complaints forced him to confront the reality of the issue, particularly the disparity in restroom wait times between genders.

Detailed Analysis and Actions Taken

With a resolve to rectify this unjust situation, Carlos took decisive steps to address the issue within the bounds of his purview, the Rotman Football Stadium. He rallied his team and launched a thorough investigation to uncover the root causes of the extended wait times. To avoid rushing into a decision and to ensure an effective solution for this unacceptable issue, Carlos held a comprehensive meeting with his colleagues a few weeks later. During the meeting, various reasons were identified to explain the extended wait times in the women's restrooms. One colleague suggested that the discrepancy in the number of toilets allotted to men and women was a contributing factor. Men had access to two toilet stalls and six urinal stalls, whereas women

Table 1. The Parameters of the Service Process

		UP, %			Class 1			Class 2		
G	AR	GS	NP	U	Prob.	ST	StD	Prob.	ST	StD
Women	3.2	0.70	0.21	0.09	0.95	1.67	1.2	0.05	5.2	3.2
Men	3.2	0.70	0.21	0.09	0.95	0.83	0.7	0.05	5.2	3.2

Note. AR: arrival rate; UP: user preference; GS: gender-segregated; NP: no preference; U: unisex; Prob.: probability; ST: service times; StD: standard deviation.

had access to only six toilet stalls at each quarter of the stadium (see Table 1). Another colleague attributed the issue to the allocation of restroom units based on the international plumbing code, which was designed nearly 20 years ago. However, the proportion of female patrons has since increased, and there is also a growing preference among patrons for unisex restrooms.

Historical Context and Current Challenges

A colleague highlighted that the fight for bathroom rights led to changes in the international plumbing code to ensure equal restroom space allocation. Rotman Stadium adhered to this rule by allocating equal square footage to both men's and women's restrooms though the number and types of toilets in each restroom varied. The code was later updated to allocate equal toilet units, but this still doesn't fully address the long wait times for women, who often accompany children or the elderly.

Another colleague shared data showing significant wait time differences between men and women and the lack of toilets for users who feel uncomfortable and unsafe entering gender-segregated restrooms. Because the stadium is old, there's no space to expand. However, he suggested that the adjacency of men's and women's restrooms could allow for practical restructuring to improve accessibility. When Carlos questioned how this would help reduce wait times for women and provide more unisex stalls, the colleague had no clear solution for optimal restroom design.

Proposed Solutions and Expert Consultation

After analyzing the long wait times faced by women and LGBTQ+ individuals in restrooms, Carlos consulted Masha Kaplan, an expert on the topic, who offered to train Carlos on the specific needs of marginalized communities, underscoring the importance of inclusive restroom designs. Through this collaboration, Carlos recognized how restroom designs can perpetuate discrimination, especially for transgender individuals, and the need for unisex toilets as a flexible solution. Masha explained that unisex toilets foster inclusivity, reduce wait times and safety concerns for marginalized groups, and improve "potty parity." Carlos, intrigued by the value of unisex toilets, asked how many were needed. Masha explained that the number depends on customer demographics and perceptions. This prompted Carlos to realize the balance between operational efficiency, customer satisfaction, and safety. He acknowledged the challenges of managing restroom capacity, especially during high-volume events, ensuring accessibility for individuals with disabilities. Operations managers such as Carlos must allocate restroom resources equitably among genders. We examine Carlos's decisions at Rotman Football Stadium to restructure restroom facilities, address long wait times, and improve accessibility, contributing to a safe, inclusive environment for all patrons.

Potential Solutions for Public Restroom Problems

Carlos found himself in a challenging situation as his team's efforts to provide an unforgettable fan experience were overshadowed by complaints about subpar restroom facilities for women and members of the LGBTQ+ community at their stadium. Inspired by Masha's insights, Carlos came to appreciate the impact a lack of understanding can have on these communities. With this newfound appreciation, Carlos and his team returned to the stadium with a fresh perspective and a mission to create an inclusive, equitable, and respectful environment for all patrons. After careful consideration, he identified potential solutions, including retrofitting toilets for accessibility, adding toilet stalls in women's restrooms, converting men's toilets to women's toilets, and creating unisex toilets for members of the LGBTQ+ community. However, Carlos knew that implementing these solutions without understanding the root cause of the issue could lead to unsatisfactory results, especially because such renovation plans are expensive. One of Carlos's team members, who holds an MBA degree in operations management, reminded Carlos of the value of data-driven decision making and analysis. He and his team aimed to identify bottlenecks and improve efficiency by applying queueing theory to model restroom wait times and convert these wait times into fairness scores. Recognizing the problem's operational and social implications, Carlos directed his team to gather data for informed decision making. With insights from the queueing model and fairness analysis, Carlos was confident in balancing operational efficiency with social equity. Despite the significant time and resource investment required, he embraced the challenge, rallying his team to create a more inclusive and equitable environment at the stadium.

Data Gathering and System Analysis

The stadium has four restroom complexes, one located at each corner of the building. The group gathered data following the bathroom bill.[1] To simplify data collection and analysis, they categorized all individuals entering the women's restroom under the "women's room" and those entering the men's restroom under the "men's room," assuming binary classification based on restroom use. This grouping facilitates estimating the arrival rates and service times for each category. Additionally, the group collected data on user preferences for gender-segregated versus unisex restrooms to ensure that accommodations align with user preferences. Individuals indifferent between the two options were classified as having no preference. Furthermore, users were divided into two subclasses based on their intended restroom usage: class 1 for urination and class 2 for defecation. Then, the data are collected on the probability that each user would belong to each class, their average service time, and the standard deviation of their restroom usage. The summary of these data is presented in Table 1. Acknowledging the variability of restroom usage data across factors, such as the day of the week, time of year, and visiting teams, Carlos utilized past data and collected new data from consecutive games, considering them representative of the entire season. Sensitivity analyses and scenario evaluations were incorporated to strengthen the analysis and address limitations in the data.

With his expertise in queueing system modeling, Carlos tasked his team with evaluating the operational efficiency (e.g., average wait time) of various restroom design options, focusing on using unisex toilets. A few redesign approaches were considered: converting some men's urinal stalls into unisex toilets or fully transforming the restrooms into all-gender facilities, in which all toilets and urinals would be accessible through a shared entrance. All proposed options were assumed to be feasible from renovation and construction perspectives.

Table 2. Women's Restroom Users' Preferences by Wait Time and Service Model

	GS		No preference		Unisex	
Wait time	GS	Unisex	GS	Unisex	GS	Unisex
0–5 minutes	5	4	5	5	3	5
5–10 minutes	4	3	4	4	2	4
10–20 minutes	3	2	2	2	1	3
20–40 minutes	1	1	1	1	0	2
40–60 minutes	0	0	0	0	0	1

Table 3. Men's Restroom Users' Preferences by Wait Time and Service Model

	GS		No preference		Unisex	
Wait time	GS	Unisex	GS	Unisex	GS	Unisex
0–5 minutes	5	4	5	5	3	5
5–10 minutes	4	3	4	4	2	4
10–20 minutes	3	2	2	2	1	3
20–40 minutes	2	0	1	1	0	2
40–60 minutes	0	0	0	0	0	1

The team debated that the optimal restroom design must ensure fairness as well. Whereas some advocated for fully all-gender restrooms to align with societal trends, others expressed concerns about fan comfort and preferred a compromise that balanced inclusivity and variety in restroom options even if it extended wait times. Carlos raised critical questions about acceptable wait times and the practicality of such changes for the stadium. To better understand user preferences, the analytics team conducted a survey. Participants were asked to select their preferred restroom type and rate their experience on a scale from zero to five, considering wait times and restroom types. For instance, a woman preferring gender-specific restrooms might rate her experience as five with a wait time under five minutes but lower her score if using a unisex restroom or facing longer delays. Conversely, a user favoring unisex restrooms might consistently rate such facilities higher regardless of wait times because of the reported social cost of using gender-segregated restrooms. The results of this survey for users of the women's and men's rooms are summarized in Tables 2 and 3, respectively.

Carlos requested a comprehensive analysis of various restroom design options with a particular focus on the use of unisex toilets to identify the optimal restroom design. Based on the data provided and the proposed design alternatives, what would you recommend to Carlos as the best renovation plan for the stadium?

Appendix A

- λ : Average arrival/output rate.
- $a = \frac{1}{\lambda}$: Average interarrival time.
- σ_a : Standard deviation of interarrival times.
- $CV_a = \frac{\sigma_a}{a}$: Coefficient of variation in the interarrival times of customers.
- μ : Average service rate.
- $p = \frac{1}{\mu}$: Average service time.
- σ_p : Standard deviation of service times.
- $CV_p = \frac{\sigma_p}{p}$.
- s : Number of servers.
- $\tau = \frac{\lambda}{s \times \mu}$: Utilization based on rate.
- $\tau = \frac{\frac{1}{a}}{s \times \frac{1}{p}} = \frac{p}{s \times a}$: Utilization based on time.

Useful Queueing Formulas

1. Note that $\tau < 1$, that is, $\lambda < s \times \mu$: The average throughput rate of the system must be strictly less than its total service (capacity) rate; otherwise, the system explodes.
2. The average wait time is calculated based on the Pollaczek–Khinchine approximation formula:
   - Average Wait in Queue $= \frac{\text{Average Processing Time}}{\text{\# Servers}} \times$ Average Squared Variability $\times \frac{\text{Probability of Wait}}{\text{Safety Capacity}}$. Mathematically,

$$T_q = \frac{p}{s} \times \frac{CV_a^2 + CV_p^2}{2} \times \frac{\tau^{-1+\sqrt{2(s+1)}}}{1-\tau}.$$

   – The probability that a customer waits, that is, $Pr\{T_q > 0\}$, which occurs when all servers are simultaneously busy, is a function of the utilization and the number of servers. This probability is calculated as $\tau^{-1+\sqrt{2(s+1)}}$. This implies lower utilization values and more servers reduce $Pr\{T_q > 0\}$.

   – Note that $Pr\{T_q = 0\} = 1 - Pr\{T_q > 0\}$ is interpreted as the probability of no wait, meaning the customer is immediately served. This occurs when at least one of the servers is not busy with a customer.

   – Safety capacity is defined as $1 - \tau$, implying that the higher the utilization, the lower the safety capacity.

3. The formula for capturing the cumulative probability of wait above a threshold t when the average wait time is T_q when service times are exponentially distributed is
   - $\Pr\{T_q <= t\} = 1 - e^{-\frac{t}{T_q}}$. Note that the cumulative probability of customers waiting above the threshold t when the average wait time is T_q is calculated as
   - $\Pr\{T_q > t\} = 1 - \Pr\{T_q <= t\}$
   - Note that this formula can be used to approximate these cumulative probabilities with nonexponential services times.
4. Time in System (T) = Average Wait in Queue (T_q) + Average Service Time $(p) = T_q + p$.
5. Little's law establishes the relationship between average inventory, average throughput rate, and average time. It can be applied to a queue, a service, or both, stating that

Average Customers in Queue (I_q)
= Average Throughput Rate $(\lambda) \times$ Average Time in Queue (T_q)
Average Customers in System (I)
= Average Throughput Rate $(\lambda) \times$ Average Time in System (T)

6. To calculate the standard deviation of service times of I heterogeneous classes of customers with different average processing times and standard deviations, you can use the following formula:

$$\text{Aggregate ST.DEV.} = \sqrt{\frac{\sum_{i=1}^{I} n_i \times (\sigma_{pi}^2 + (p_i - p_{all})^2)}{N}}.$$

For two heterogeneous classes of customers, the expanded formula is as follows:

$$\text{Aggregate ST.DEV.} = \sqrt{\frac{n_1 \times (\sigma_{p1}^2 + (p_1 - p_{all})^2) + n_2 \times (\sigma_{p2}^2 + (p_2 - p_{all})^2)}{N}}.$$

- n_1 and n_2 are the average arrival rates of class 1 and 2 customers, respectively. Note that $N = n_1 + n_2$.
- p_1 and p_2 are the average processing times of class 1 and 2 of customers, respectively. Note that $p_{all} = \frac{n_1}{N} \times p_1 + \frac{n_2}{N} \times p_2$.
- σ_{p1}^2 and σ_{p2}^2 are the standard deviations of class 1 and 2 of customers, respectively.
- The merging of the flow of two heterogeneous classes of customers introduces additional variance: $(p_i - p_{\text{all}})^2$ because of the disparity in their average processing times and the weighted average of the two classes of customers.

Endnote

[1] In some states, the bathroom bill requires individuals to use gender-segregated restrooms according to their gender identity, whereas in others, they must comply with the gender assigned at birth.