Priority Management on Service Platforms with Waiting Time Differentiation

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1. Motivation

Several examples of waiting time differentiation exist, both on service platforms, and in other industries.

Parcel delivery

Priority delivery
Loyalty program

Boost option

Airline boarding

Tipping system

Priority pickup
Wait-and-save

1. Motivation

- The central idea is to account for heterogeneity among customers concerning their **willingness to wait** and **to pay**.
    - The businessman vs. the student.
- **Several options for an almost identical service** with the quality mainly determined by the **experienced waiting time**.
- Such a practice can be valuable:
    - **Faster service** for impatient customers.
    - **Discounted price** for patient customers.
    - The platform alleviates the total waiting cost endured by the customers, and extracts some part of the created value.

1. Motivation

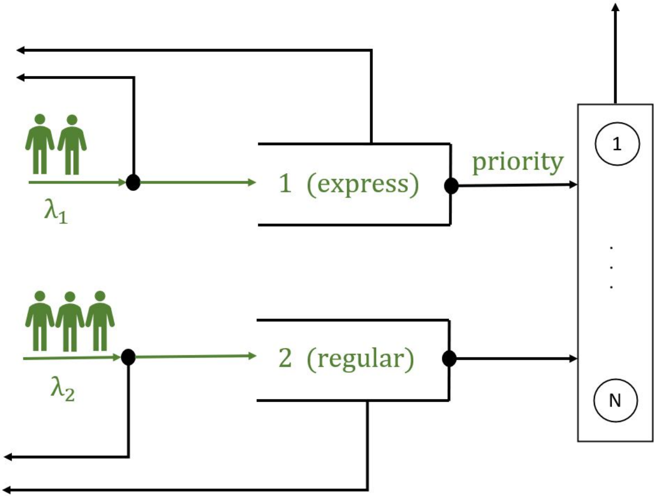
In this talk, we focus on the following questions:

1. How to allocate the service providers to the classes of customers (reservation control)?
   - Serving express customers vs. Serving regular customers.
2. When to admit customers to the system (admission control)?
   - Admitting customers vs. Avoiding abandonment.
3. How do these decisions affect the platform and its users (customers and service providers)?

1. Related Literature

- **On-demand service platforms**: Cachon et al. (2017), Taylor (2018), Bai et al. (2019), Bimpikis et al. (2019), Powell et al. (2020), Banerjee et al. (2021), Jacob and Roet-Green (2021) etc.
- **Waiting time differentiation**: Mendelson and Whang (1990), Jayaswal et al. (2011), Afèche and Pavlin (2013, 2016), Maglaras et al. (2018), Jacob and Roet-Green (2021), etc.
- **Controlled queueing systems**: Koole (1998, 2007), Altman et al. (2001), Savin et al. (2005), Benjaafar et al. (2010), Iravani et al. (2012), etc.

2. Problem Setting



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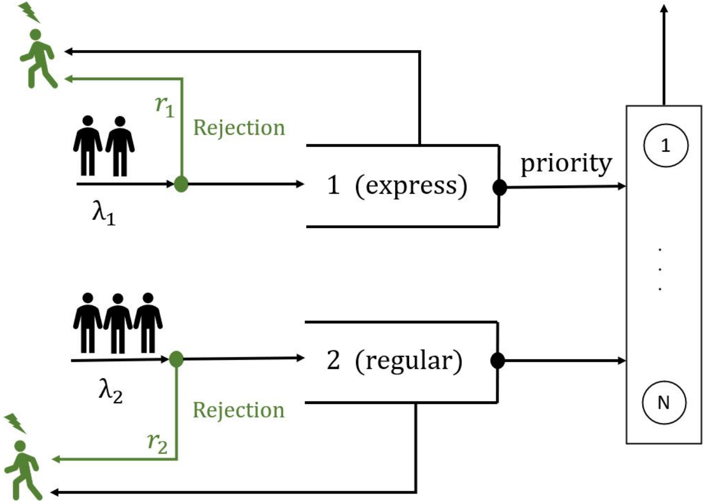

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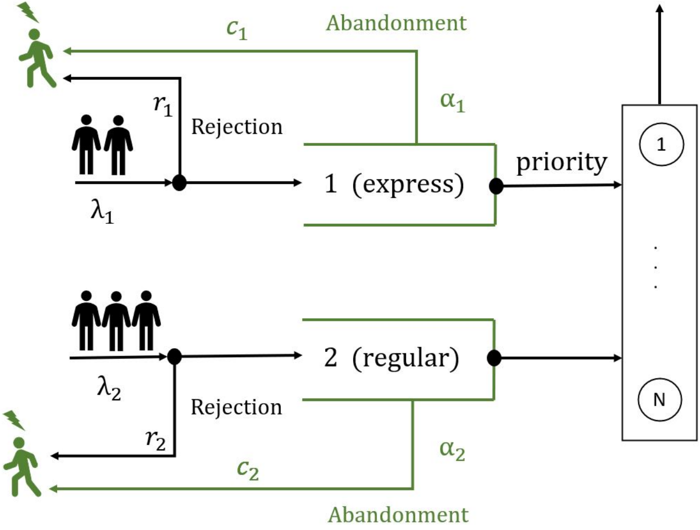

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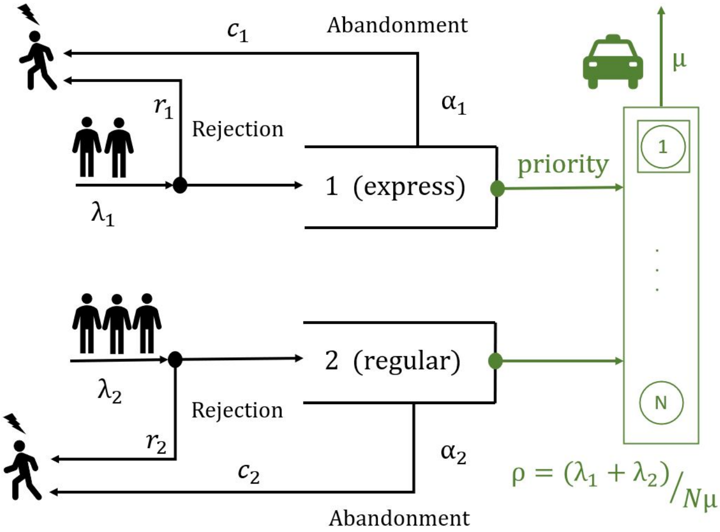


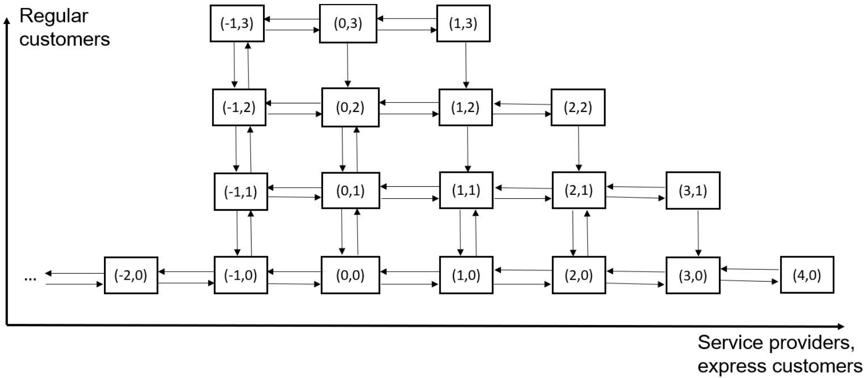
2. MDP Formulation

We can formulate this setting as an MDP.

- **State**: Number of service providers/express customers waiting (x) and regular customers waiting (y).
- **Decisions**: Customer admission and service provider reservation.
- **Costs**: Abandonment (c_i) and rejection (r_i).
- **Transitions**: Arrival of an express customer, regular customer or service provider, and abandonment of an express or regular customer.

2. System Dynamics

Using standard dynamic programming techniques (e.g., relative value iteration), we can derive the cost-minimizing policy π^*.



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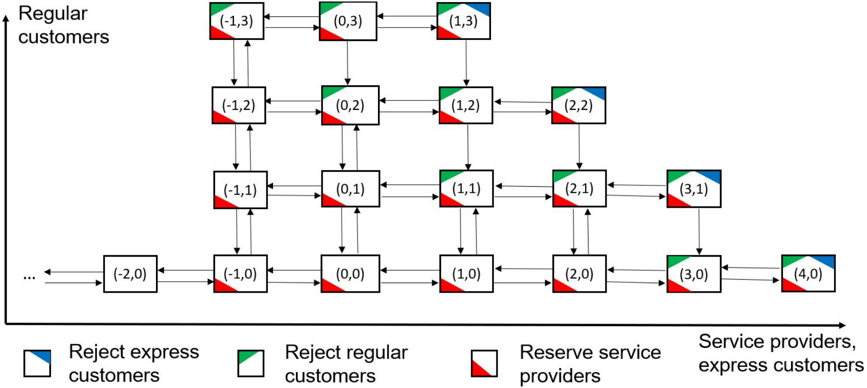


3. Existence of Admission Thresholds

We define the value iteration operator as

$$\begin{aligned} v_{n+1}(x,y) &= T[v_n(x,\ y)] \\ &= \lambda_1\ T_1[v_n(x,\ y)] + \lambda_2\ T_2[v_n(x,\ y)] + N\mu\ T_3[v_n(x,\ y)] \\ &+ M_1\,\alpha_1\ T_4[v_n(x,\ y)] + M_2\,\alpha_2\ T_5[v_n(x,\ y)], \end{aligned}$$

where $\lambda_1 + \lambda_2 + N\mu + M_1\alpha_1 + M_2\alpha_2 = 1$.

Lemma

Let $\mathcal{V}$ be the set of functions that satisfy the following properties:

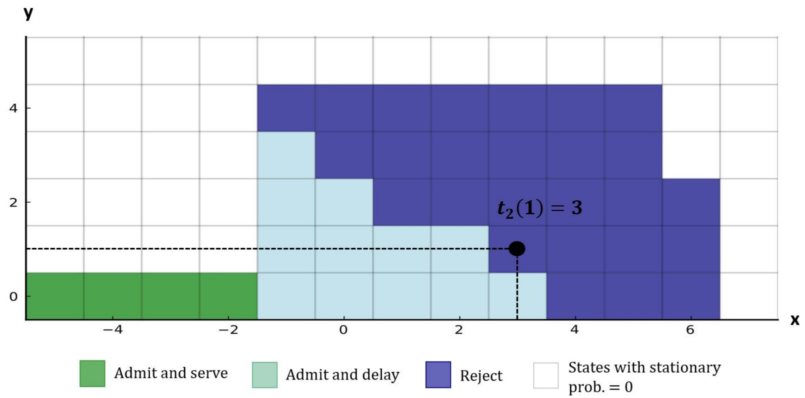
- $v\,(x+1,y)\ +\ v\,(x,y+1) \leq v\,(x,y)\ +\ v\,(x+1,y+1)$,
- $v\,(x,\ y) \leq v\,(x+1,\ y)$,
- $v\,(x,\ y) \leq v\,(x,\ y+1)$,

If $v \in \mathcal{V}$, then $T[v] \in \mathcal{V}$ and $v^* \in \mathcal{V}$.

3. Illustration of Admission Thresholds

Proposition

Customers are admitted if and only if the number of customers in **the opposite queue** does not exceed some critical value.



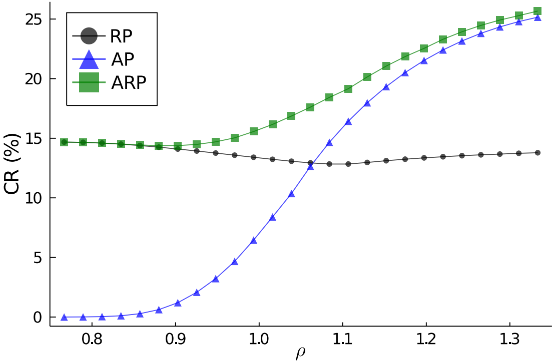
4. Experimental Setting

We compare the policy found by our MDP (ARP) with three simpler policies:

1. The **simple priority policy (SP)**: No control (non-preemptive priority).
2. The **reservation policy (RP)**: Control over the reservation of service providers.
3. The **admission policy (AP)**: Control over the admission of customers.

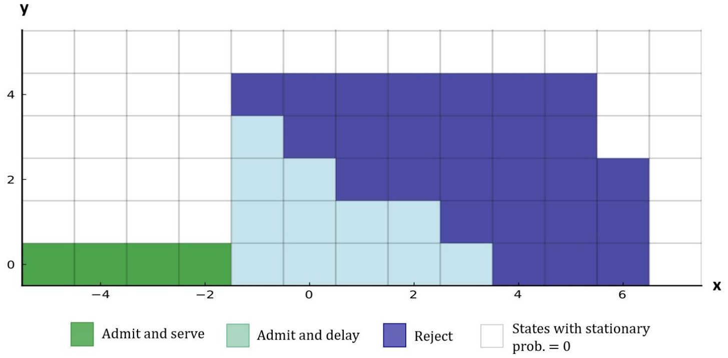
We take SP as baseline to isolate the effects of admission and reservation control when used alone (AP, RP), or jointly (ARP).

4. Cost-Related Benefits



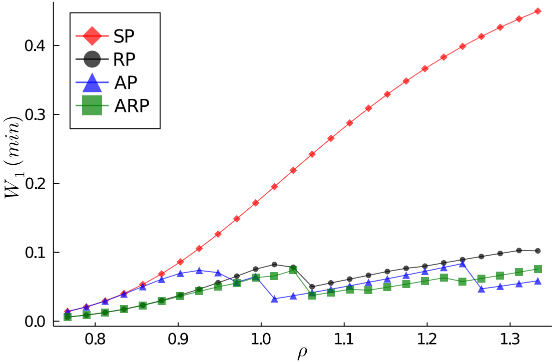
- Low workload $\rightarrow$ Reservation control.
- High workload $\rightarrow$ Admission control.
- Balanced workload $\rightarrow$ Reservation and admission control.

4. Cost-Related benefits



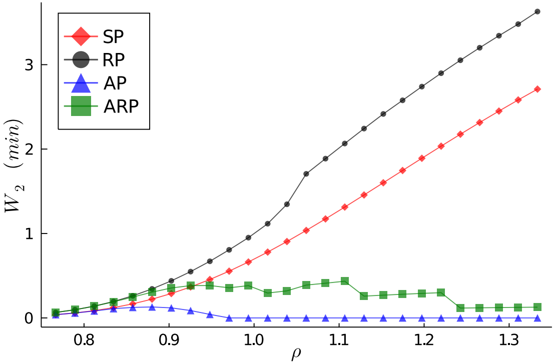
- Few customers waiting $\rightarrow$ Admit and delay.
- Many customers waiting $\rightarrow$ Reject.

4. User-Related Benefits



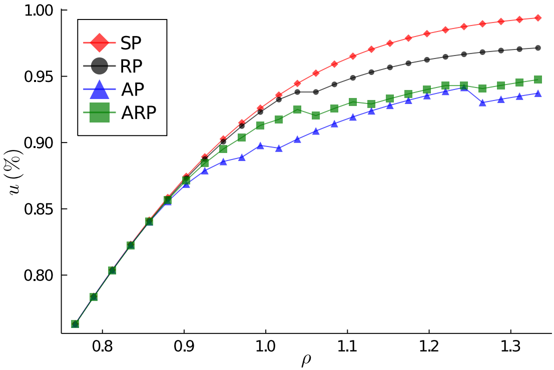
- Admission and reservation control both ensure low waiting times to express customers.

4. User-Related Benefits



- Reservation control increases the waiting times of regular customers.
- Admission control alone can lead to waiting times that are not incentive-compatible.

4. User-Related Benefits



- All the policies maintain a high utilization rate.
- Setting the right compensation scheme for service providers (e.g., fixed commission rate) may circumvent this issue.

5. Conclusion

Summary:

- Our model finds an policy characterized by two admission thresholds and one reservation threshold.
- It benefits from the interplay between admission and reservation control:
  - Significant cost reductions.
  - Shorter and incentive-compatible waiting times.

Contributions:

- A stylized model for on-demand service platform with waiting time differentiation.
- Analytical results on the structure of the optimal policy.
- Value of admission and reservation control.