**Tele-Driving**

Tele-driving refers to a novel concept where drivers can remotely operate vehicles (without being physically in the vehicle).

**Examples of companies built around tele-driving technology**

- Vay
- Starship
- Einride

**Advantages of Tele-Driving**

- Remote drivers can be treated as a common resource (the system could operate with fewer drivers than vehicles)
- Tele-driving could reduce inefficiencies associated with drivers acting strategically and increase driver utilization
- Tele-driving could eliminate discriminatory behavior by the drivers and increase the safety of both drivers and riders

**Ride-Hailing with Tele-Drovers**

- A ride-hailing platform operates with \( m \) vehicles and \( n \) remote drivers with \( m \geq n \) (\( m = n \) is equivalent to a traditional ride-hailing system)
- To serve a customer, the platform assigns an idle remote driver to the vehicle that is nearest to the origin of the customer request
- The driver takes over the control of the vehicle and drives it remotely to pick up the customer and then transport the customer to her destination

**Tele-driving could operate with both drivers and riders**

**A Spatial Queueing Model**

- Demand process: Poisson process with rate \( \lambda \) where origin-destination pairs associated with each requested trip are uniformly distributed over the service region.
- Service times: state-dependent exponential distribution with rate \( \mu(q) \) which satisfies

\[
\frac{1}{\mu(q)} = \frac{s}{\sqrt{m - q} + 1} + s,
\]

where \( q \) is the number of customers being served and \( s \) is the expected travel time between two uniformly drawn locations. Note that \( q \leq n \), where \( n \) is the number of drivers (servers).

**Results**

Depending on the number of vehicles relative to the workload, the system can be in one of three regimes: a supply-limited regime, an intermediate regime, and a supply-rich regime.

**Impatient customers**

- Supply-limited regime: reducing the number of drivers can lead to a higher service level (the improvement can be significant)
- Intermediate regime: reducing the number of drivers can similarly lead to a higher service level (the improvement can be insignificant)
- Supply-rich regime: although reducing the number of drivers always leads to a lower service level, the decrease in service level can be small even when the decrease in the number of drivers is significant (asymptotically, this decrease is at least a half)

**Patient customers**

- Supply-limited regime: the system, regardless of the number of drivers is unstable (customer delay is not finite)
- Intermediate regime: reducing the number of drivers can make a system that is otherwise unstable stable
- Supply-rich regime: it is possible to significantly decrease the number of drivers while only marginally increasing customer delay (asymptotically, this decrease is at least a half)

**An intuitive explanation:**

1. Having fewer drivers reduces "service time": pick-up time decreases with the number of idle vehicles and having fewer drivers than vehicles reduces pick-up times
2. Having fewer drivers reduces the number of "servers":

The relative strength of these two counteracting forces crucially depends on the number of vehicles relative to workload.

- When the system is short on vehicles, the effect of shorter pick-up times is strong
- When the number of vehicles is large, the effect of shorter pick-up times is weak

**Numerical Results with New York City Data**

- We use TLC data, which includes the GPS coordinates of pick-up and drop-off times and locations, to approximate the customer arrival process.
- A rider is matched with the nearest vehicle (in terms of travel time).
- The pickup time is approximated by the travel time along the shortest path, and the service time is approximated by the trip time from the TLC data.

**Numerical results using NYC taxi data**

- In the supply-limited regime (panel (a)), a system with remote drivers can improve service level by 20.7%.
- In the supply-rich regime (panel (b)), a system with remote drivers can reduce the number of drivers by 42% while maintaining a similar service level.