



PONTIFICIA
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What about Transit? CAV's and Urban Mobility

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¿autonomous buses?



¿autonomous buses?

Does it make sense?

Where are the benefits?

Is it really possible?



Autonomous public transport has been around for decades



Modern Metro systems are **driverless** or have drivers that do not drive

And driverless cars are already here....

This innovation seems to be ignoring buses.

If we consider automation in buses....

which should be the first step for buses towards automation?

Driverless Metro seem feasible because of rails and a fully segregated way

But...



The conflicts with other vehicles and pedestrians for a bus in a **corridor** are much easier to predict than for a car moving in regular traffic

Thus, automatizing buses should start with buses operating in corridors.

According to www.brtdata.org there are 452 BRT corridors in 205 cities worldwide, serving more than 34 million passengers per day.

The benefits from automatizing for these passengers would be huge.

A centralized coordinating control can become the rails for these buses and much more

Some potential **benefits** of driverless operation

Smoother bus docking at stations

Safety

Traffic signal priority

Eco-driving

Schedules (waiting times and transfers)

Headway regularity

What do people **seek** when travelling in public transport?



Fast



Low waits



Comfortable



Reliable

How can we **achieve** these attributes?



Fast

**DECREASE
TRAVEL TIME**

INCREASE SPEED



Low waits

**INCREASE
FREQUENCY**

**INCREASE FLEET
OR
INCREASE SPEED**



Comfortable

**INCREASE
TRANSPORT CAPACITY**

**INCREASE FLEET, VEHICLE SIZE
OR
INCREASE SPEED**



Reliable

**DECREASE
TRAVEL TIME VARIABILITY**

REGULAR HEADWAYS

How can we **achieve** these attributes?



Fast



Low waits



Comfortable



Reliable

INCREASE SPEED!

AND THEN MAYBE IF WE
HAVE SPARE TIME FOCUS
ON REGULAR HEADWAYS....

How can we **achieve** these attributes?



Fast



Low waits



Comfortable



Reliable

**INCREASE SPEED
AND
REGULAR HEADWAYS!**

Vehicles in public transport systems
behave like magnets....

Regular intervals is an **unstable** equilibrium



Any perturbation and the **equilibrium is lost**... all around the world.

Bus bunching... found in London



Bus bunching... found in **Beijing**



Bus bunching... found in **Santiago**



Today we will address **three questions**

- 1 Why does bus bunching happen?
- 2 What are the impacts?
- 3 Does it have a solution?

Why does **bus bunching** happen?

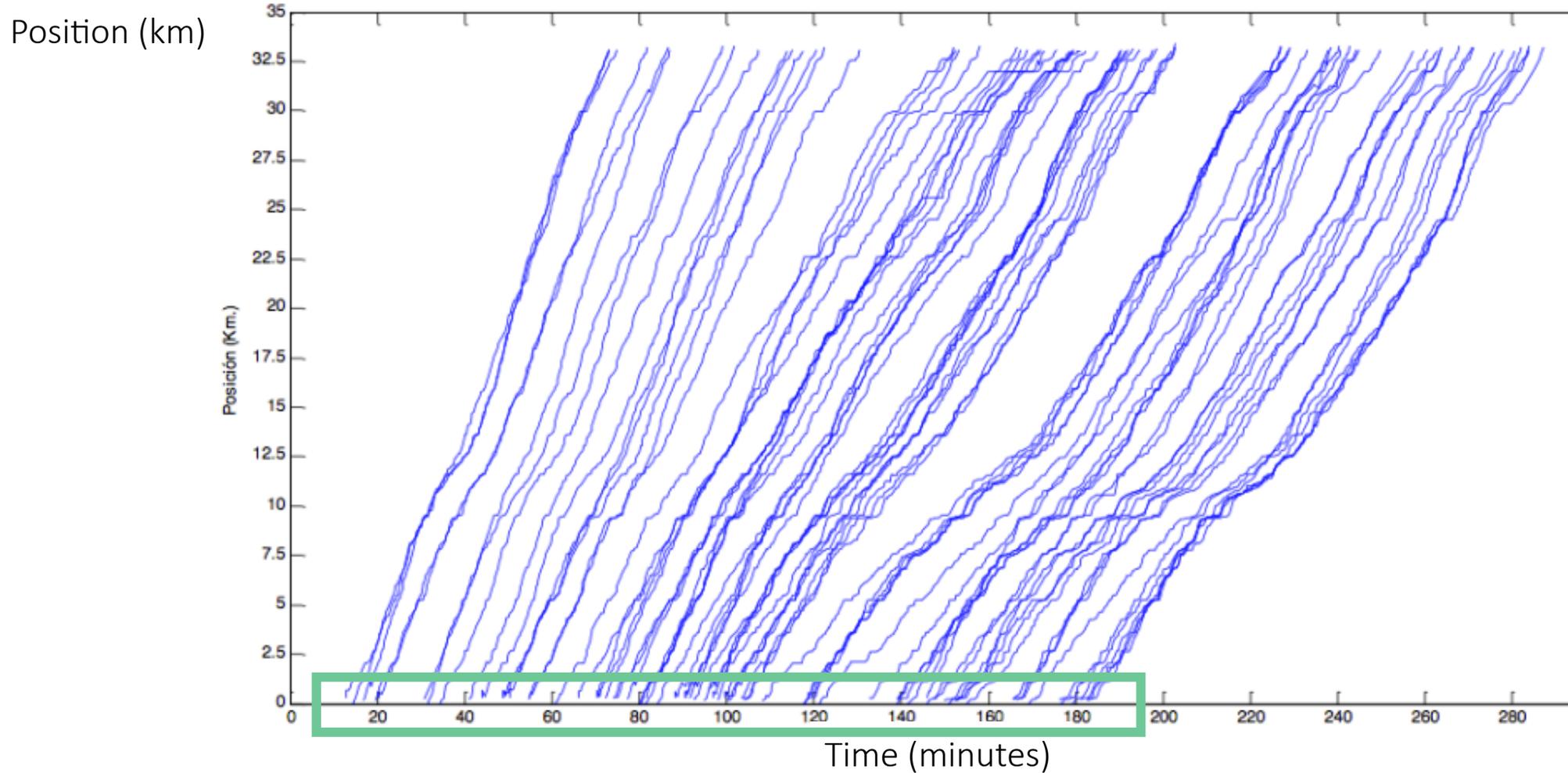
Dispatch **strategy**

Speed variability

Travel time variability

Dwell time variability

Why does bus bunching happen?



Why does **bus bunching** happen?

Dispatch strategy

Speed variability

Travel time variability

Dwell time variability

Why does **bus bunching** happen?

Travel time variability



Congestion

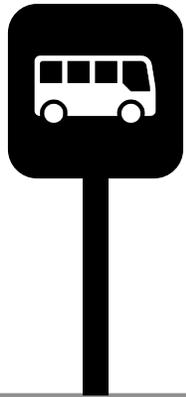


Traffic lights

Driver heterogeneity

Why does **bus bunching** happen?

Dwell time variability



Stochastic passenger arrivals
at each stop

Capacity of
buses and stops

Today we will address **three questions**

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What are the **impacts**?

Impacts are various, affecting:

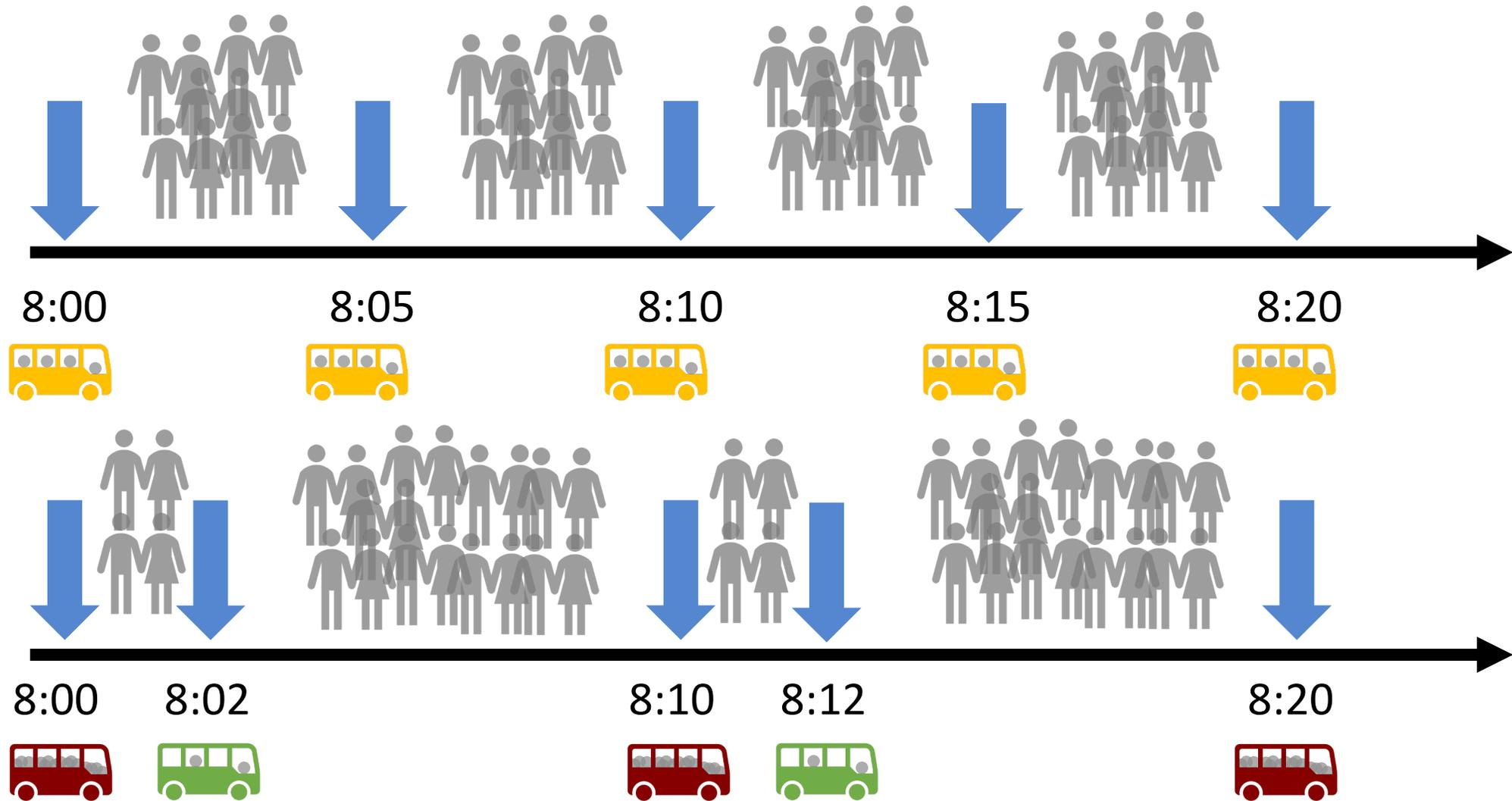


Users

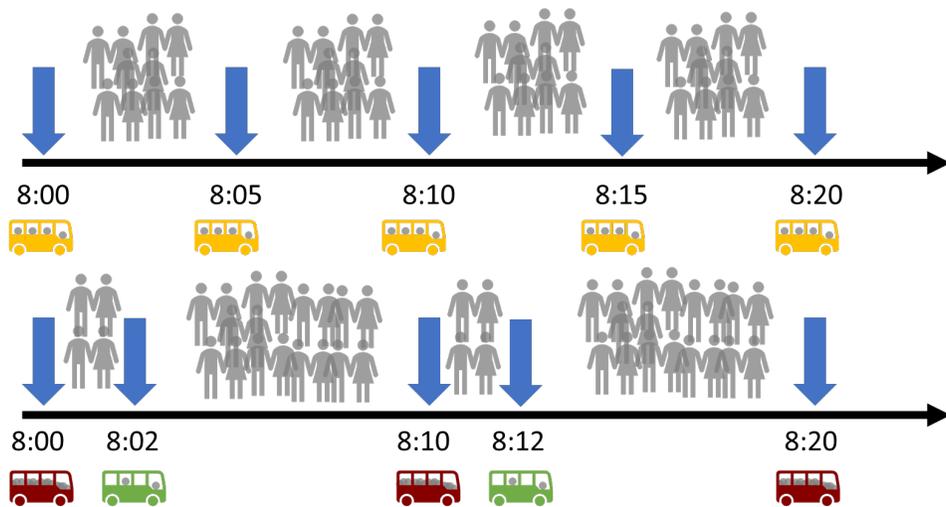


Operators

What are the **impacts?**



What are the **impacts**?



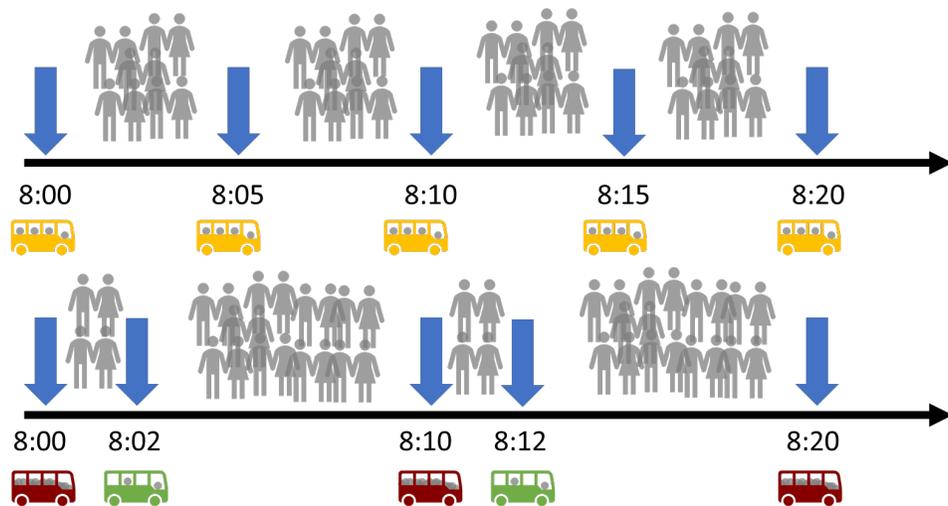
Waiting times grow

One minute of waiting is perceived as two or three minutes of in-vehicle time

Waiting times variability grow

Leads to earlier departures for users

What are the **impacts?**



Average crowdedness grow

Longer waiting times correlate with high occupancy

More users suffer high occupancy

Users tend to remember the worst experiences

What are the **impacts**?



Dwell times grow

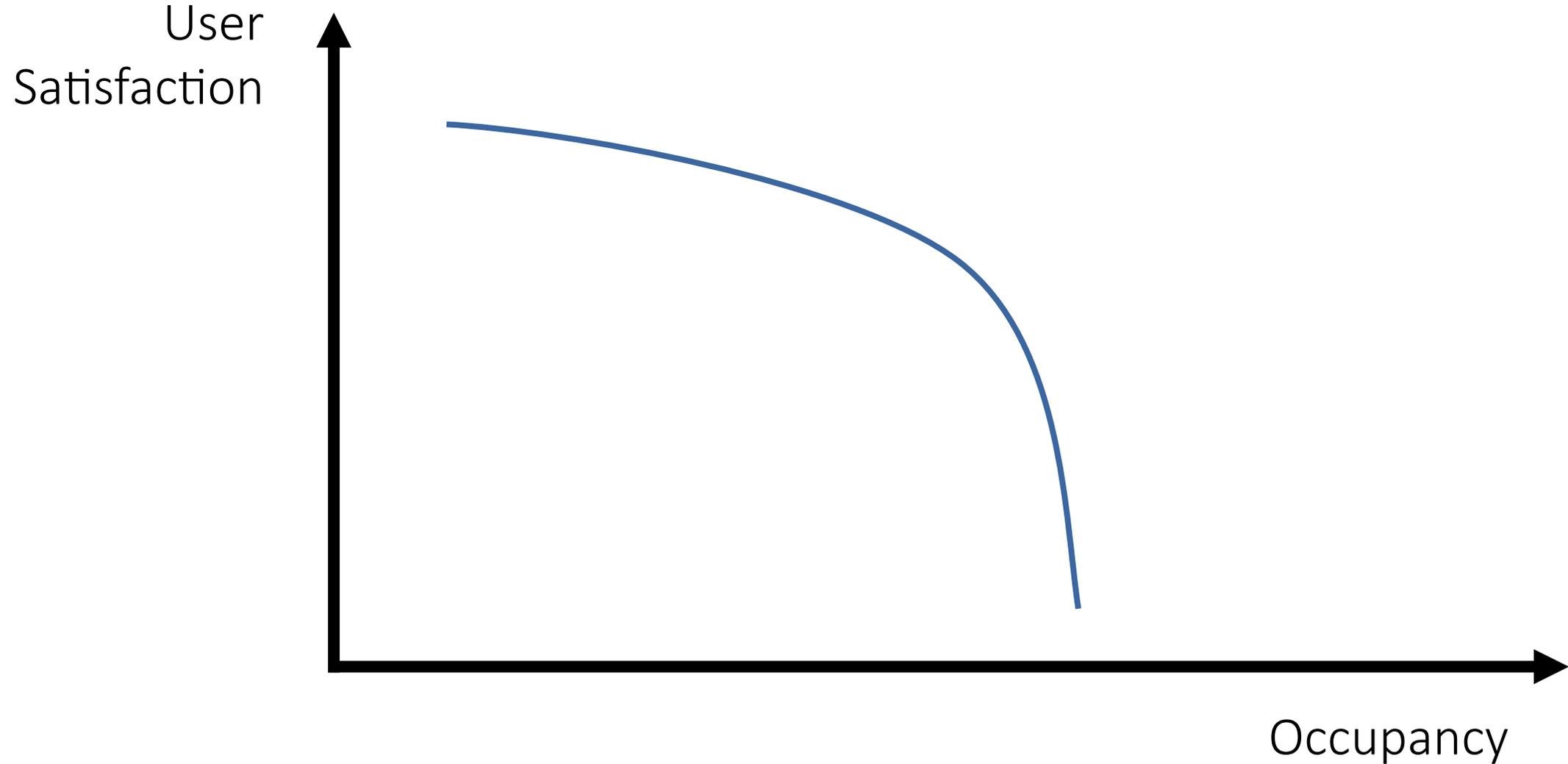
Boarding and alighting is slow creating friction that damages the experience

Speed drops....

Cycle times variability grows

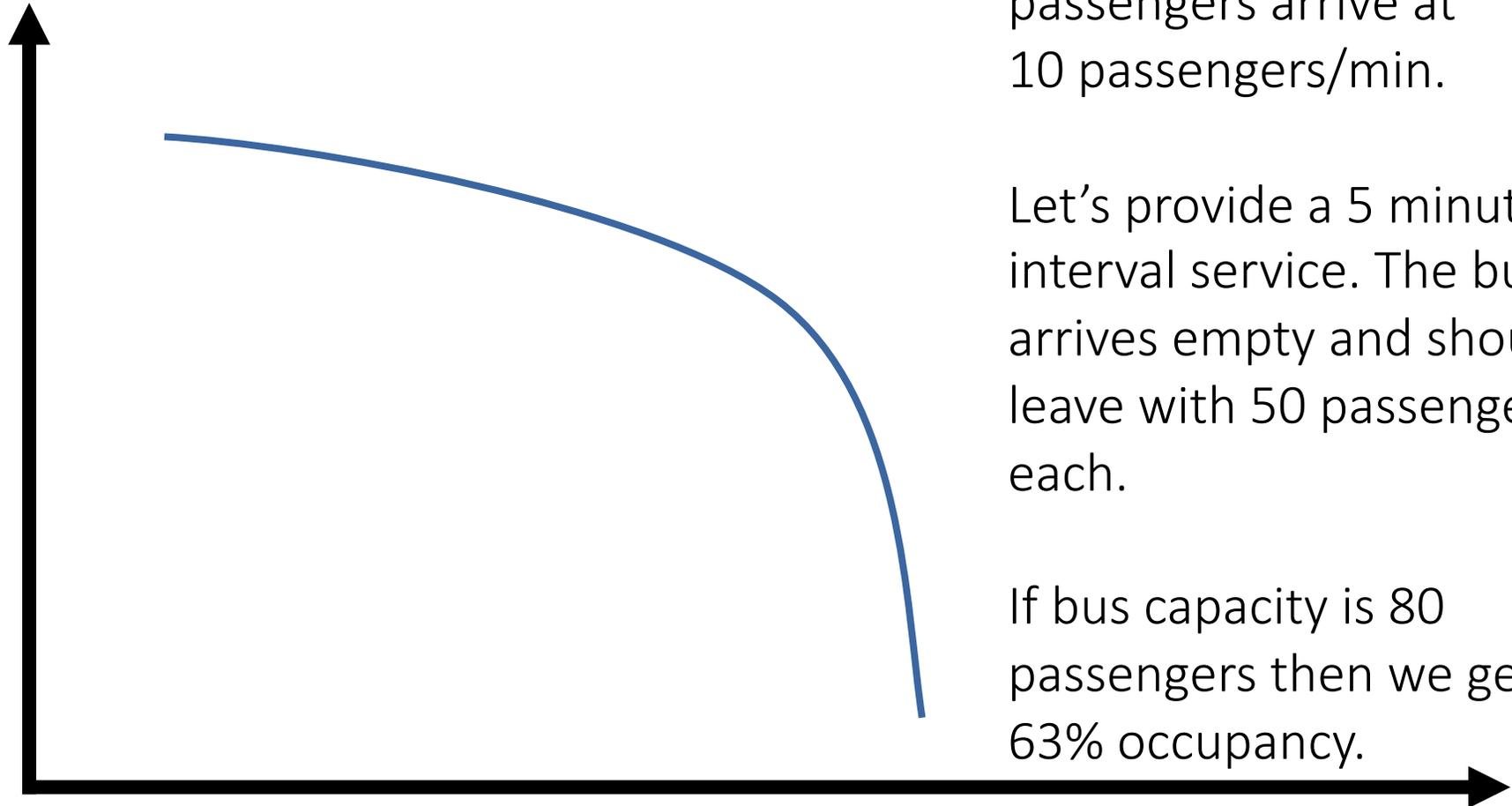
Operators need extra fleet and drivers due to variable cycle times

What are the **impacts**?



What are the **impacts**?

User
Satisfaction



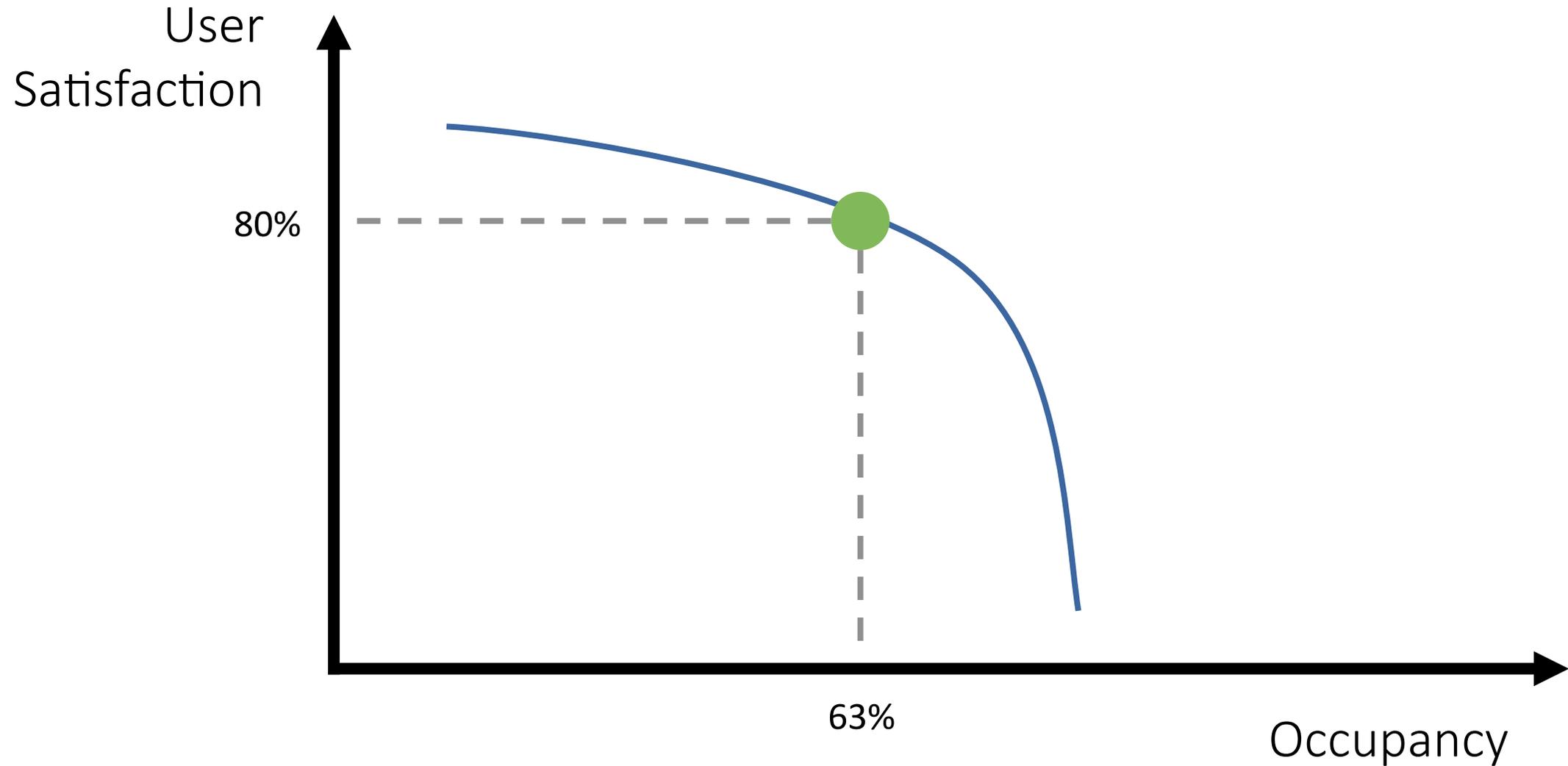
Imagine a service that must be provided at a stop where passengers arrive at 10 passengers/min.

Let's provide a 5 minute interval service. The bus arrives empty and should leave with 50 passengers each.

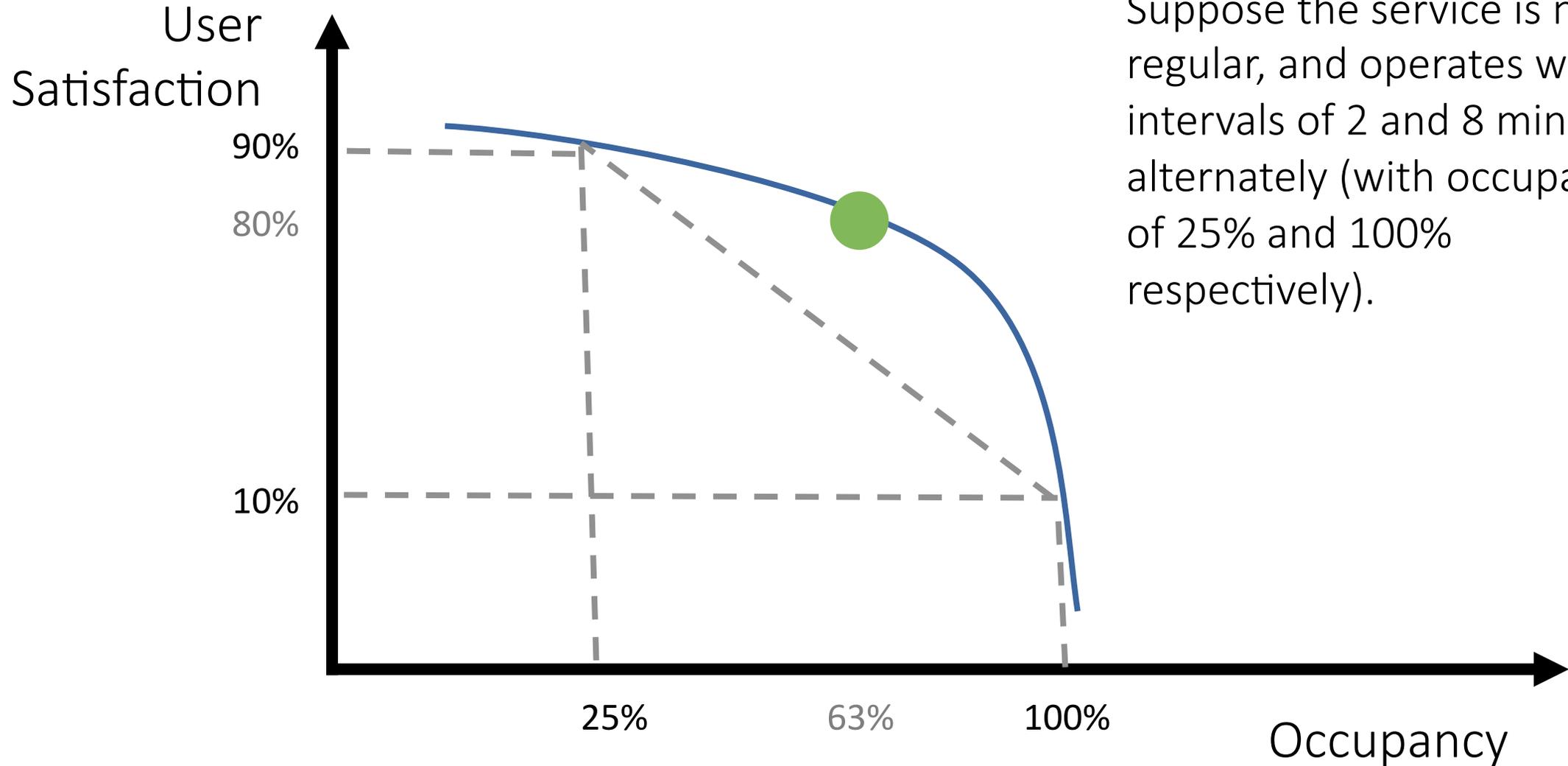
If bus capacity is 80 passengers then we get 63% occupancy.

Occupancy

What are the **impacts**?

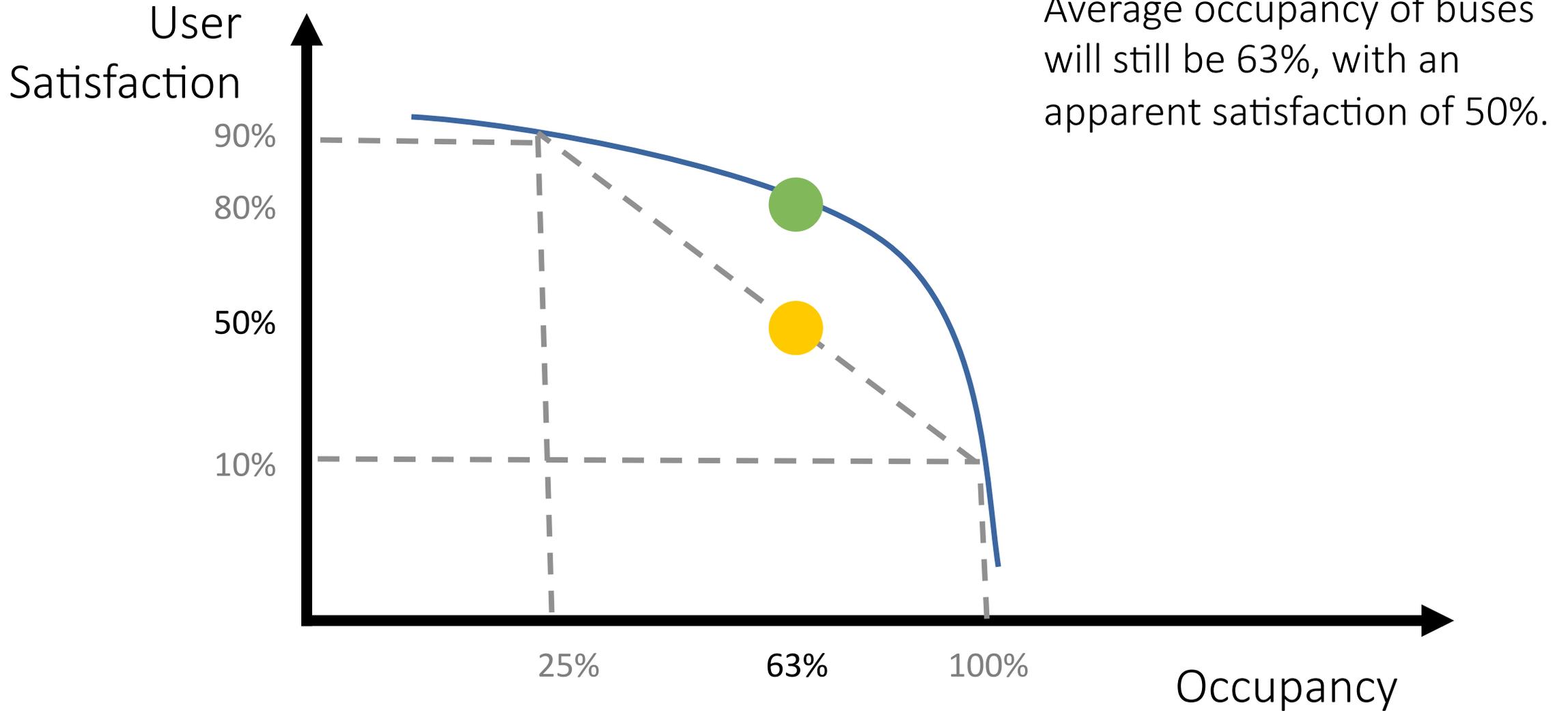


What are the **impacts**?

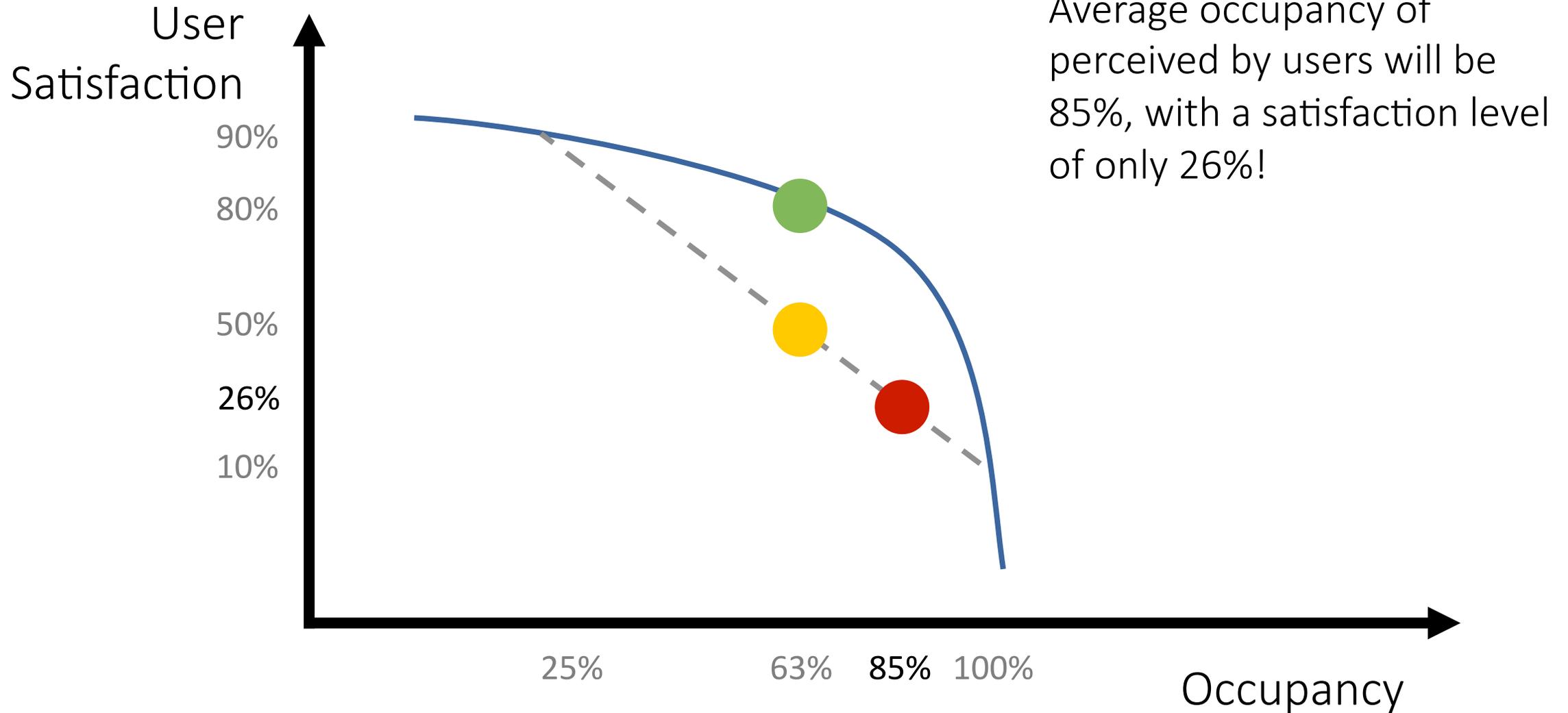


Suppose the service is not regular, and operates with intervals of 2 and 8 minutes alternately (with occupancies of 25% and 100% respectively).

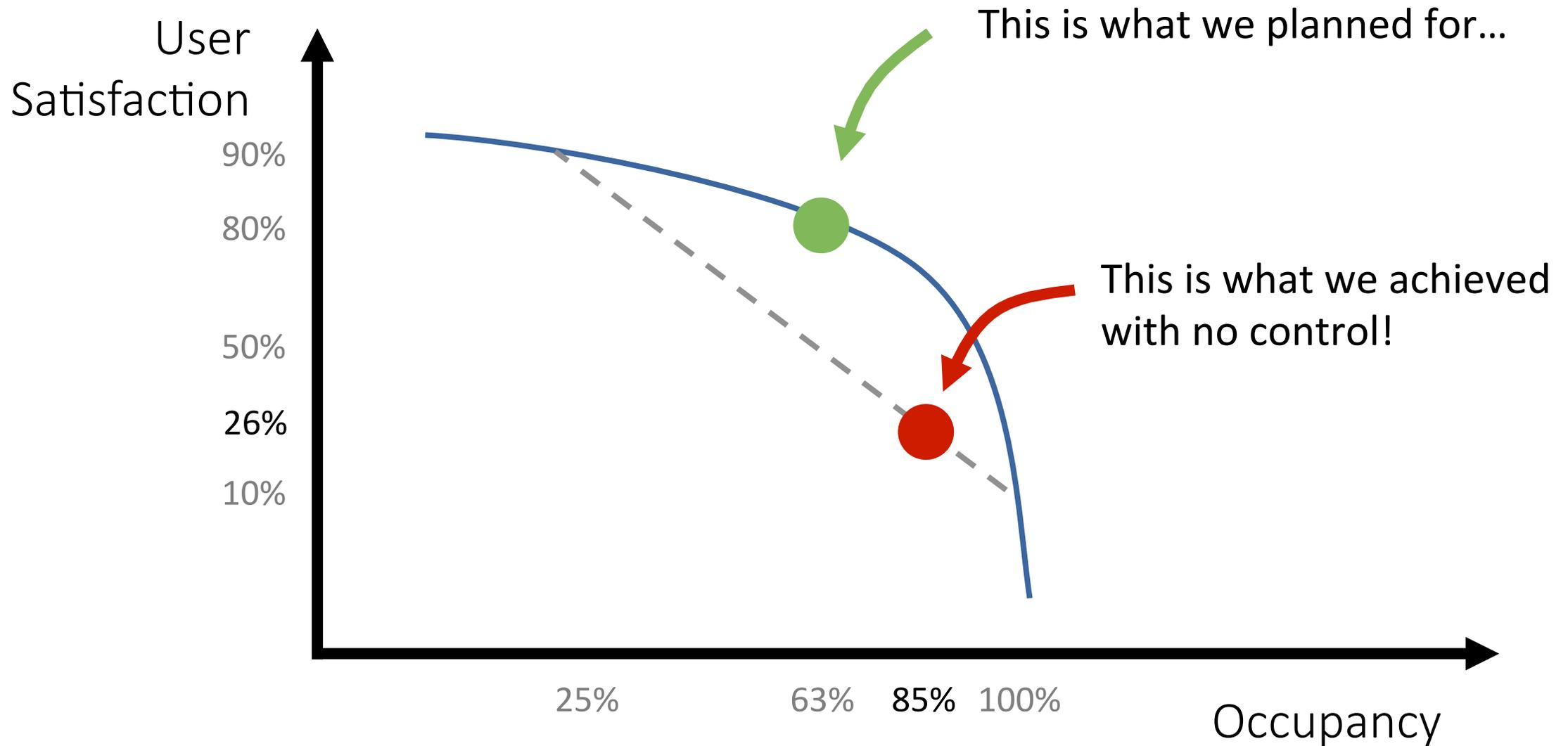
What are the **impacts**?



What are the **impacts?**



What are the **impacts**?



How can we **achieve** these attributes?



Fast



Low waits



Comfortable



Reliable

I N C R E A S E S P E E D

A N D

R E G U L A R H E A D W A Y S !

Today we will address **three questions**

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Does it have a **solution**?

Yes!

Dedicated infrastructure

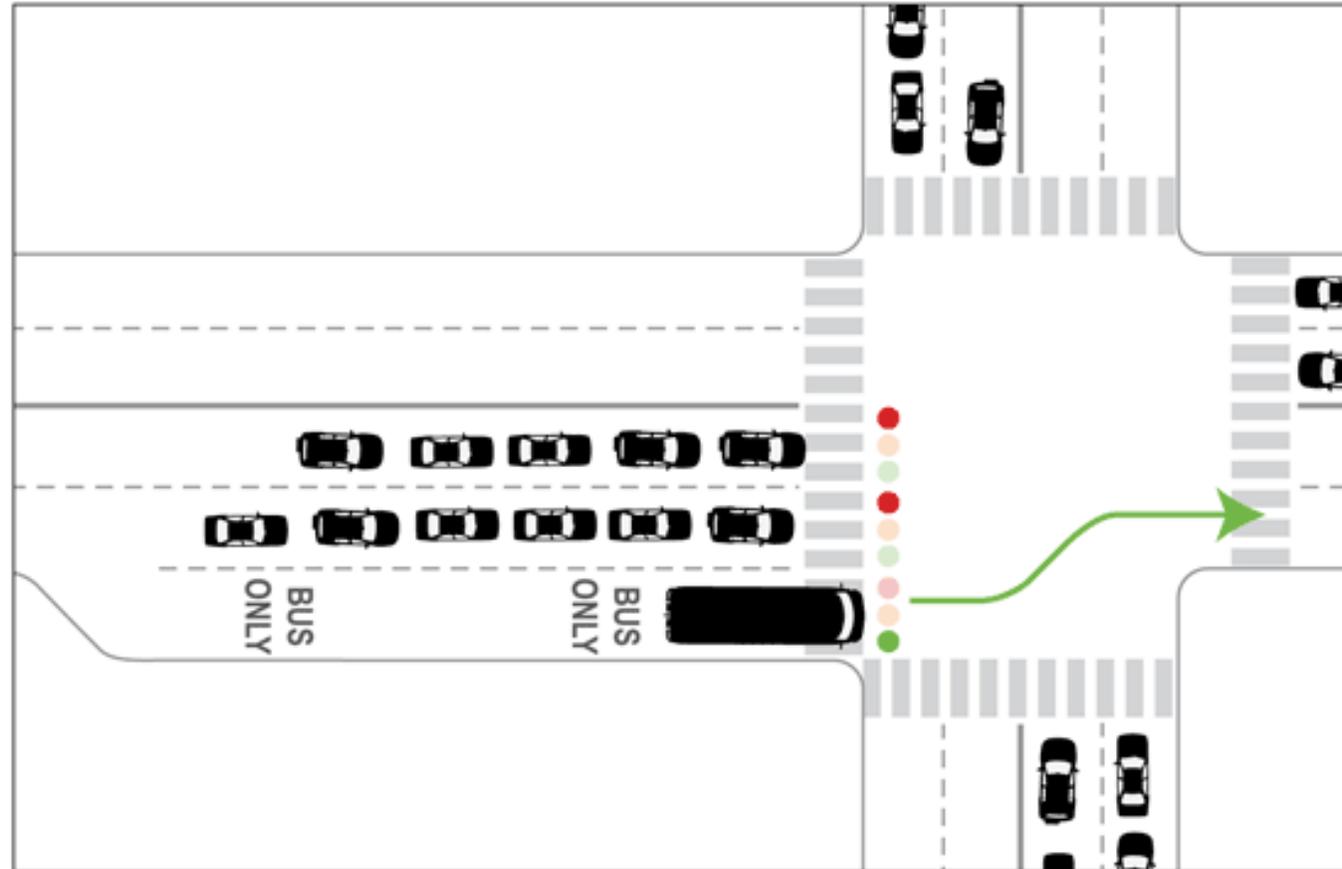
Transit signal priority

Real-time control at dispatching
and along the route

Does it have a **solution**?



Does it have a **solution**?



Source: mto.gov.on.ca

Does it have a **solution**?

TransitUC



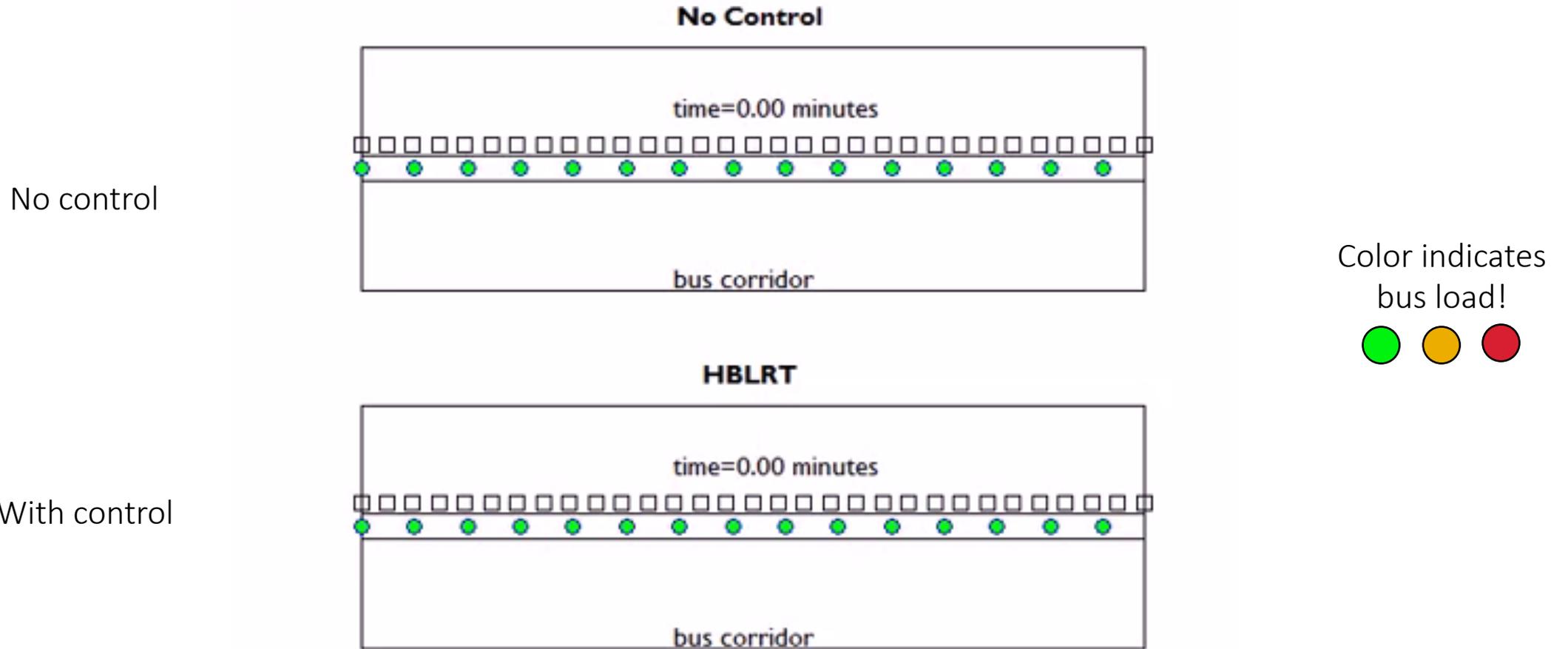
Ok!

Hold

Go faster
(if possible)

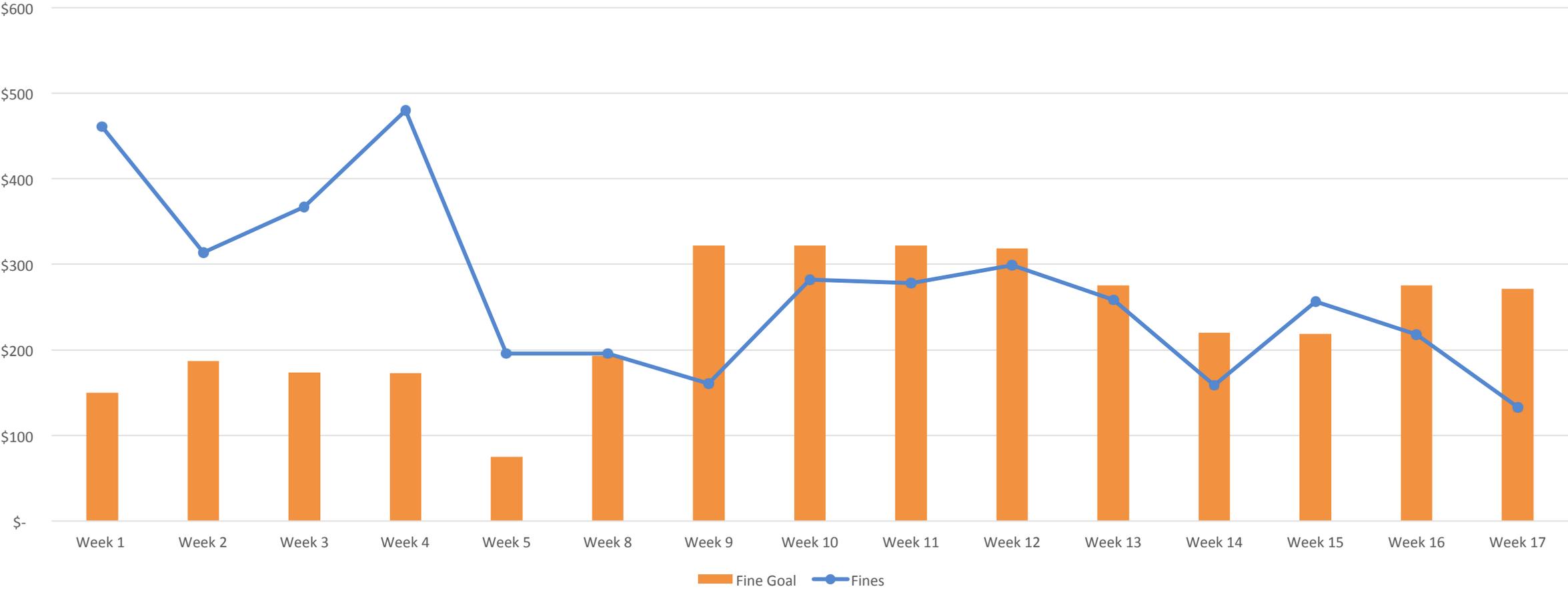
Slow down

Does it have a solution?

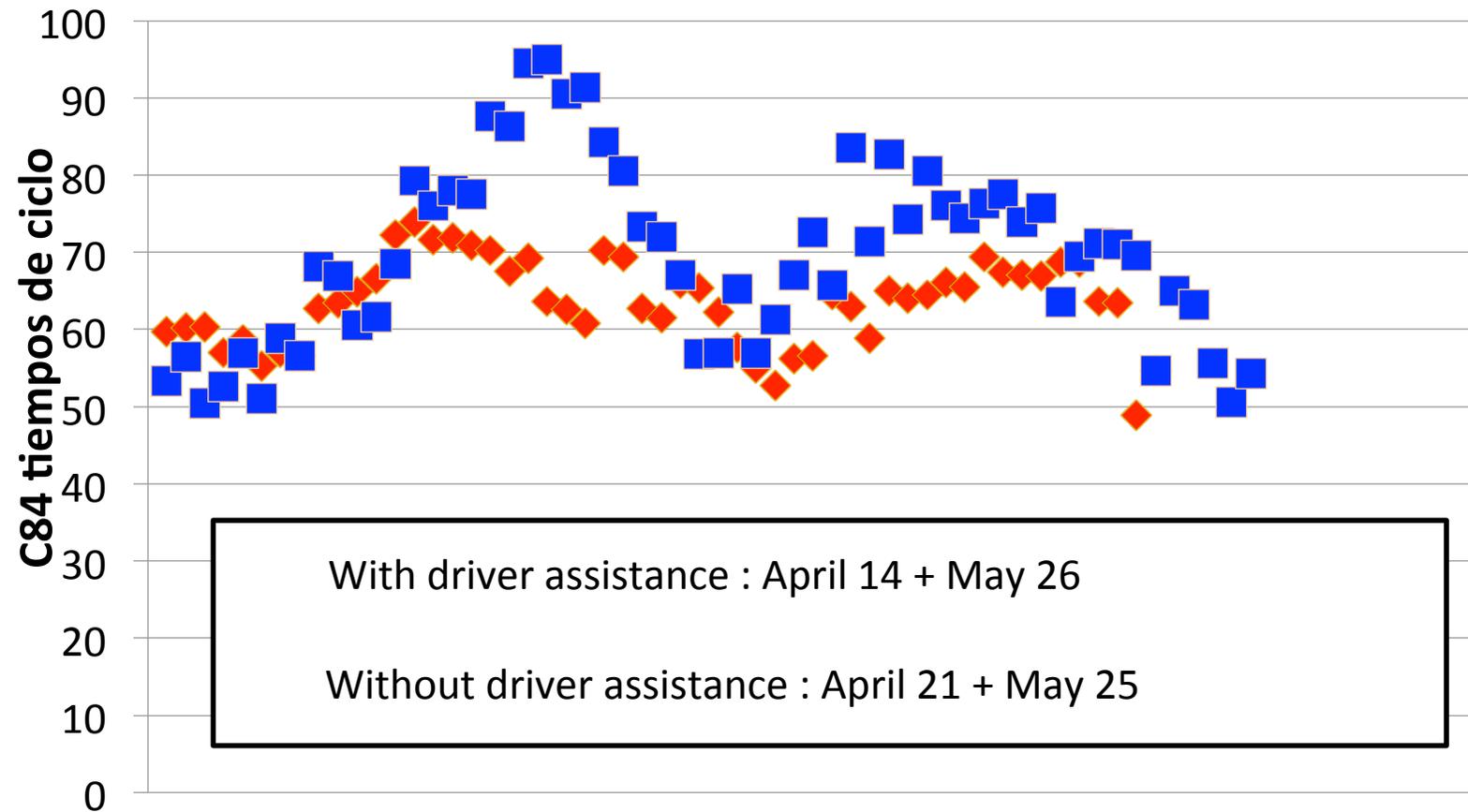


TransitUC in Transantiago

B14 + B22 Otubound Fines at Dispatching Point - 2017



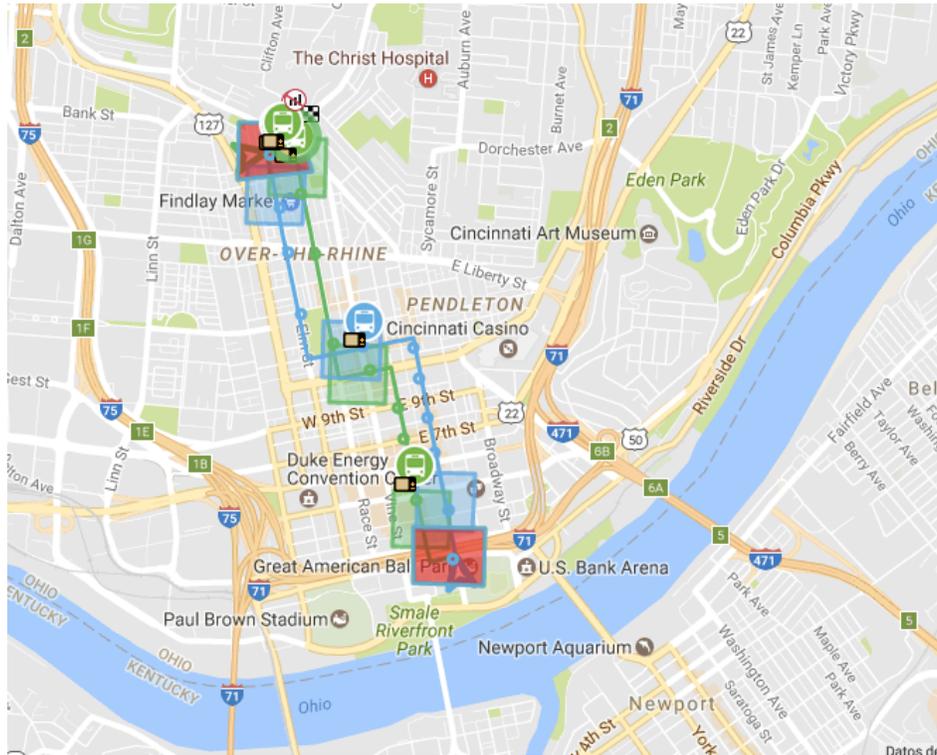
Transmilenio in Bogota



With driver assistance: cycle time = 63,4 min & Std Dev = 5,6 min

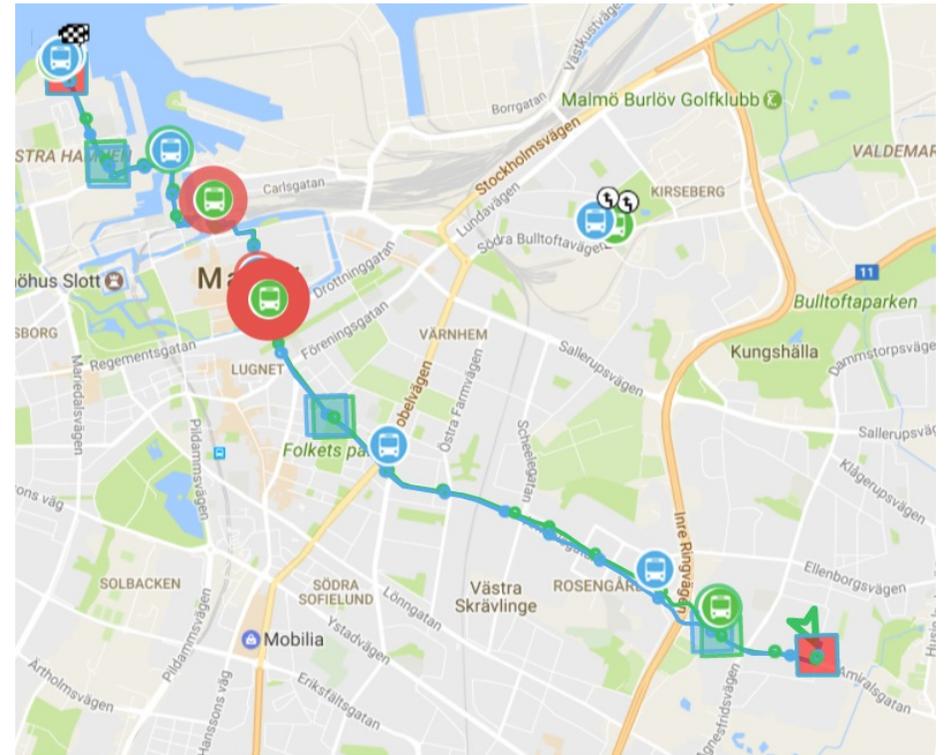
Without driver assistance: cycle time = 69,5 min & Std Dev = 11,8 min

Cincinnati Streetcar



5 streetcars
12 minute headway

Route 5 - Malmö BRT



16 BRT buses
5 minute headway

Open versus closed BRT

Some cities are operating **open BRT corridors** in which buses join and leave the corridor providing a direct trip for some journeys.

In such cases the driver should only drive while the bus is not in the corridor.

Notice that drivers are the critical link....

We have shown that (Phillips et al, 2014) it takes few drivers not obeying instructions systematically to severely damage the benefits

In the path towards automatizing...put **buses** first!



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