Spatial Rents, Garage Location, and Competition in the London Bus Market

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Firm Location Matters

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    - Transportation costs / distance to consumers / product space / local monopoly rents
    - Economies of density

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2. In urban context, actual spatial location matters
   - Congestion and pollution externalities of transporting goods & people across space
3. But models combining these features can quickly become intractable
   - See e.g., Oberfield, Rossi-Hansberg, Sarte and Trachter (2024)

We use characteristics of London bus market to estimate structural model of spatial location choice with competition and economies of density

What is this paper about?

1. Market for public bus transport in London: show that location of bus garages particularly important for firm's profitability
2. Structural model links value of Bus Garage to profits of Bus Route procurement, spatially — location in network of garages and routes
3. To estimate model: exploit changes in the garage-operator network since privatization of industry in 1994 — constructed from archival data and bus spotter sites
4. Use model estimates to quantify efficiency properties of garage ownership

London Buses are Privately Owned and Operated

Transport for London (TfL) procures bus route operation services from private firms.

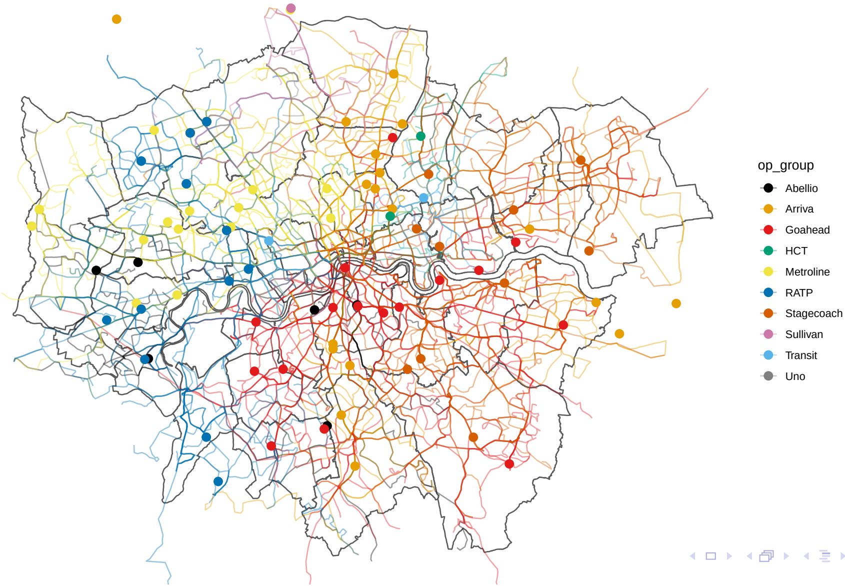
(a) GoAhead (b) Arriva and Metroline (c) StageCoach

Figure: Three examples in front of Drayton House (UCL Econ, Euston Road)

The London Bus Market

- London Buses transport 6m passengers on 675 routes per day.
- Since 1994, bus routes are tendered in recurring auctions.
- Procurement costs £273m per year.
- Today the market is dominated by a few large (international) transport firms

Garage operator network



Role of garages in procurement

- Contracts last for 5 years and specify *all* details of operations: route, frequency, vehicle type, minimum performance standards, etc.
  - See also Cantillon and Pesendorfer (2007)
- **Bid = Revenue** of operator
  - Demand-side is fixed here, no competition for passengers
  - Bus ticket fare goes to TfL
- Key source of competitiveness: **location of privately owned garage**
  - Dead Miles = driving empty between garage & route
  - Much lower for realized ($\sim$ 12 mins) than potential ($\sim$ 40 mins)
  - Descriptive evidence towards this end based on bid data

What are dead miles?

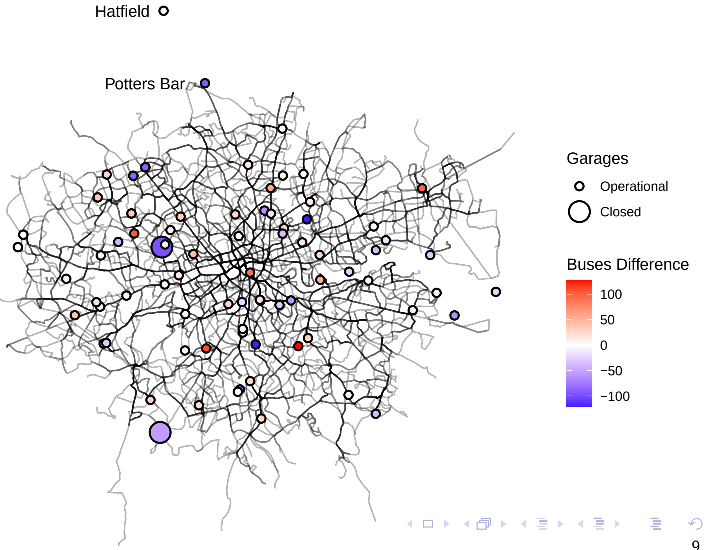
- *Distance travelled by revenue-gaining vehicles without carrying passengers*
- We find: 13% of London bus drive times are *dead*
- Empirically relevant for bids and route allocation

Dead Miles are inflated due to garage ownership constraints

Results from Companion Paper Marra and Oswald (2024)

We simulate an Unbundling Policy

- A Central Planner
  - Minimizing total dead miles
  - Respecting all constraints
  - Reduces dead miles by 14%



Introducing a Structural Model

Three Stages in period t: (firms are myopic beyond current period t)

1. Operators (i) observe current garage network and draw idiosyncratic cost shocks $\{\nu_{irt}\}_{r=1}^{R}$ for each route r

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Formalizing link between stage 2 and 3

- Derived under Independent Private Values, no route synergies, and no collusion
- But bid data / these assumptions not used in estimation.

Introducing a Structural Model

Linking stage 2 garage location and stage 3 profitability

Cost to operate route r by operator i (from closest garage) in period t:

$$\begin{aligned} c_{irt} &= \text{RouteSpecificCosts}_{rt} + \beta \text{DeadMiles}_{irt} + \alpha \text{DensityGarages}_{it} + \nu_{irt} \\ &\equiv \delta_{irt} + \nu_{irt} \end{aligned}$$

where δ_{irt} deterministic and $\nu_{irt} \sim^{i.i.d.} F_\nu$ private information.

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- So the expected profits equal $\big(b_{irt} - c_{irt}\big) Pr(win|b_{irt})$,
- and the symmetric eqm. bid $\sigma^*(c_{irt})$ solves (Guerre et al. (2000))

$$b_{irt} = \sigma^*(c_{irt}) = c_{irt} + \frac{Pr(win|\sigma^*(c_{irt}))}{Pr'(win|\sigma^*(c_{irt}))}$$

Linking stage 2 garage location and stage 3 profitability

- With N_t bidders following $\sigma^*(\cdot)$, and with $c_{irt} = \sigma^{*-1}(b_{irt})$

$$Pr(win|b_{irt}) = 1 - \underbrace{\prod_{h \neq i \in \{1,\ldots,N_t\}} Pr(\nu_{hrt} + \delta_{hrt} \leq \sigma^{-1*}(b_{irt}))}_{\text{Pr any competitor has lower cost than } \sigma^{*-1}(b_{irt})}$$

- the expected procurement profit is decreasing in $DeadMiles_{irt}$ (if $\beta > 0$), and increasing in $DensityGarages_{it}$ (if $\alpha < 0$) and $DeadMiles_{hrt}$ of competitor h (if $\beta > 0$)

Linking stage 2 garage location and stage 3 profitability

In stage 2, infer **value of garage j, π_{ijt}** in stage 3 as:

$$\pi_{ijt} = \sum_r \left[(\sigma^*(c_{irt}) - c_{irt}) Pr(win|\sigma^*(c_{irt}))\right]$$

This shows that π_{ijt} is

- ... decreasing in distance to route network ($\beta > 0$)
- ... decreasing in distance to own garage network ($\alpha < 0$)
- ... increasing in distance of competing garages to route ($\beta > 0$)

"Spatial Rents" — local monopoly rents, dead miles transportation costs, and agglomeration benefits

Data

- We build a Garage-operator-route database.
  - Garage Ownership and which Routes operated from them
  - Provided by **London Omnibus Traction Society**
  - Complemented with bus spotter / hobbyist sites and geo-coded (`londonbusroutes.net`, `londonbuses.co.uk`, `countrybus.org`, `bus-routes-in-london.fandom.com`, `wikipedia.com`)
  - Locations of all bus stops from TfL
- TfL publishes tender data since 2003
  - For auxiliary analysis only — empirical results based on changes in operator-garage network (i.e., stage 2 of the structural model)

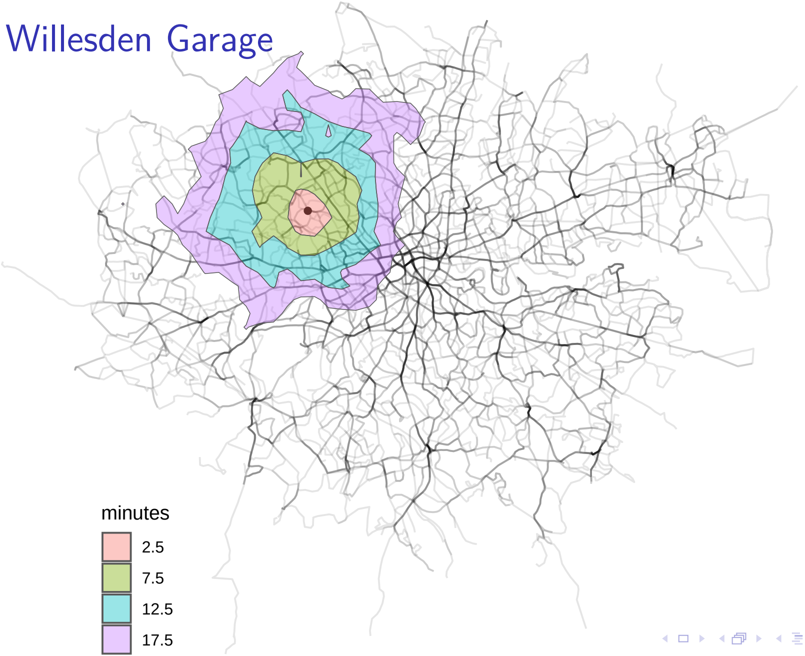
Garage-Operator-Route database

Which operator runs which route from which garage. Garage Capacity. Garage Names and Locations.

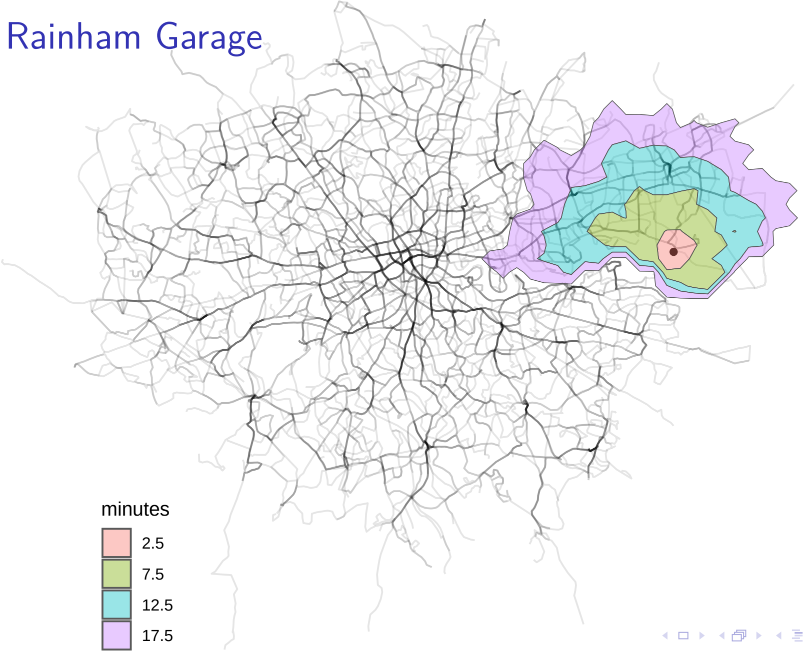
(a) Stockwell Garage

(b) Waterloo Depot

Drive times Willesden Garage



Drive times Rainham Garage



Garage Ownership (Changes)

- We observe 192 *garage-operator network changes* between 1995–2019 $\rightarrow$ taking place on *change-dates* (t)
- So, ownership changes are infrequent.
- We observe extremely few *new* garages (building restrictions) and assume those away – set of garages is fixed over time!
- We call a garage which does not exist anymore (or not yet): *vacant*.
- Some garages change owners very often – others never.

Garage Choice Model

Setup

At time t the data show an $\mathcal{N}$ to $\mathcal{J}$ **matching** between operators and garages. In reality, operators transact garages. However

1. Only one operator per garage
2. Observe changes sequentially (usually one change per t)
3. And recall that garage network is held fixed

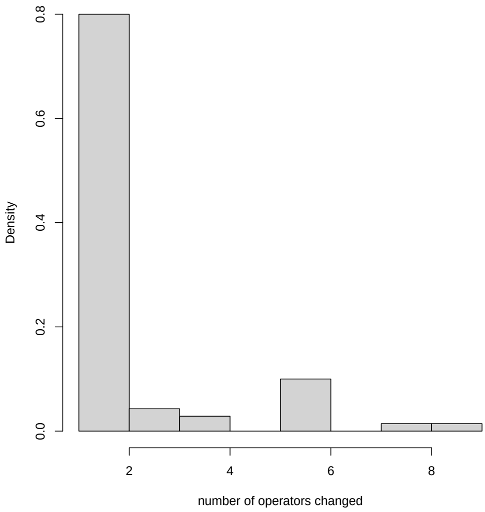
Garage Choice Model

Setup

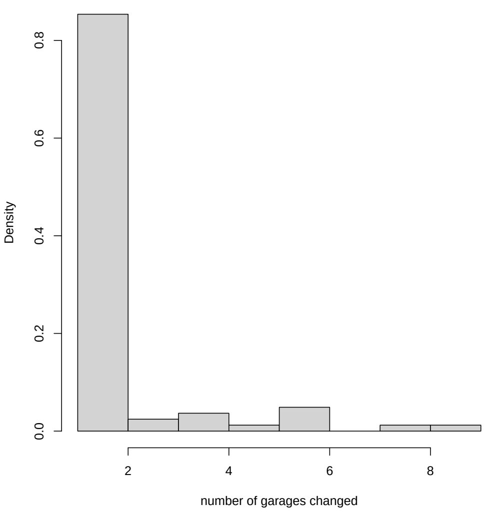
We can then flip the problem, to $\boxed{\text{garages choose operators}}$

1. Garage j chooses among all operators the one that has highest π_{ijt}
2. Sequentially, given garage network at t
3. Market price to buy garage same for all operators, so cancels out
4. Vacant also $\in \mathcal{N}$, $i = 0$, mean utility normalized to 0
5. Key simplifications: static model, no bundled choice

(a) # Operators changing garage



(b) # Garages entered by operator



Garage Choice Model

Reduced form stage 2 garage network formation

- Model utility of garage j - operator i match as

$$\pi_{ijt} = \pi(\Gamma_j^X, \Gamma_{ijt}^C, \Gamma_{ijt}^O) + \epsilon_{ijt}$$

  - Γ_j^X: distance j to *route network* — (Dead Miles)
  - Γ_{ijt}^C: distance j to Competing garages — (Local Monopoly Rents)
  - Γ_{ijt}^O: distance j to Own garages — (Agglomeration Benefits)

- We parameterize π as a linear function and ϵ_{ijt} with nested logit structure (vacant, non-vacant)

Estimation Results - preferred specification

	(5)
No. bus route starts within 10 min. drive time	0.025
Min. drive time to any own garage	-0.199***
No. comp. garages within 10 min. drive time	-0.636***
Incumbency benefit [$exp(-T_{jt})$]	2.624***
Garage is not vacant	1.858*
Inclusive value	2.755***
Pr(highest-utility operator correctly predicted)	0.385
Own garage proximity (mins) offsets extra comp. garage	3.205
McFadden's pseudo-R^2 w.r.t. Null Model (ρ_0^2)	0.491
Number of Choice Situations	192

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

- Significant Inclusive Value justifying nested logit: *the market* $\neq$ active firms
- Sizeable Economies of Density and Local Monopoly Rents
- Persistence through Incumbency Benefit, offset with +1.5 competitors after 1 year

Is That a *Good* Garage Choice Model?

Ultimately, garage entry process is more complex. We abstract from dynamics, bundled choice, and —due observing only 192 choice situations— rely on simple representations of network variables.

But parsimonious model with 5 variables + nesting structure fits surprisingly well

- McFadden's ρ^2's "excellent fit"
- *Identity* of highest-utility operator right in $\sim 40\%$ cases
- Frequency-weighted *Area Under Curve* ~ 0.9
- Good average entry frequencies by operator

Summary of the rest of the paper

Counterfactuals

1. Magnitude of *Hold Out Problem*?
   - In 11% of cases, another operator benefits more from garage than incumbent
   - Efficiency loss between 6.5-9.8 % London bus procurement costs

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   - Pattern of non-realized transactions consistent with market sharing
   - In line with operator behavior other UK bus markets (CMA 2011 report)

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   - In line with operator behavior other UK bus markets (CMA 2011 report)
3. Urban planning : where to build garages? [in progress]
   - Adding garage capacity, land values, and route-operator contract details to model

Conclusions

1. Build custom dataset of London bus garage ownership and document spatial segregation of operators
2. Propose equilibrium model of garage choice
   - Linking garage value to route revenues, identifying spatial rents
3. Use model + data to estimate garage-operator utility function
   - Simple nested logit explains well changes garage-operator network
   - Important: own garage clustering, isolation from competing garages, incumbency benefit
4. Show that private garage ownership generates efficiency loss
   - Holdout Problem: amounting to 6.5-9.8% of procurement costs
   - Temporal pattern consistent with collusive market-sharing

Application 1: Garage Hold Out Problem

Operators might be holding on for too long to their garages.

- Consider all garages where no change took place on date t.
- Compute utility difference with incumbent's utility: $\hat{\psi}_{ijt} = \max(0, \hat{\pi}_{ijt} - \hat{\pi}_{Ijt})$

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  - Summing $\frac{\hat{\psi}_{ijt}}{\hat{\psi}_{Ijt}}$ across all operator-garage-time triples
- Given markup estimates, this loss represents 6.5% – 9.8% of the total London bus procurement cost
- Results from private ownership of garages

Providing a foundation for the Ownership Frictions found in companion paper Marra and Oswald (2024)

Application 2: Collusive market-sharing behavior *outside London*

UK Competition Commission 2011 report, on conduct bus operators outside London:

- *"[...] operator* ***conduct by which operators avoid competing with other operators*** *in 'Core Territories' (certain parts of an operator's network which it regards as its 'own' territory)* ***leading to geographic market segregation****."*

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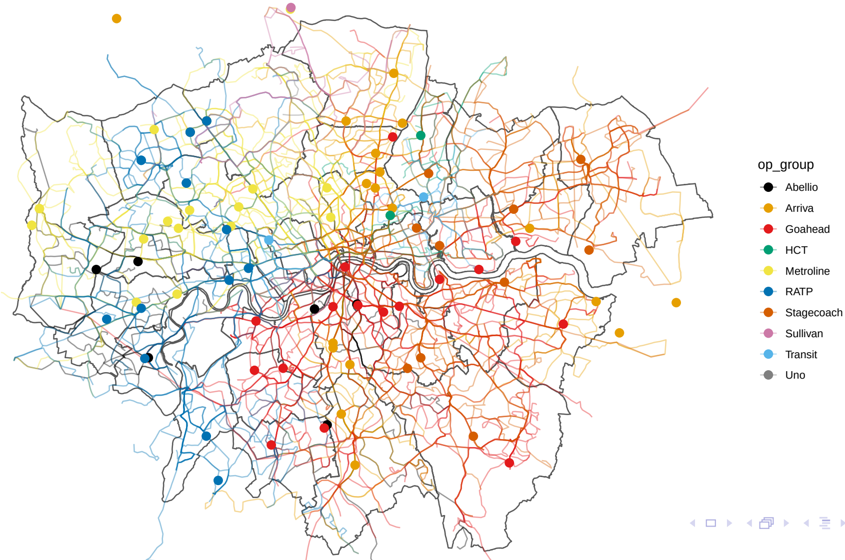
- *"We have seen **retaliatory conduct** in several areas, and **consideration of retaliation** elsewhere [...]"*
- *"[...] concerned that geographic market segregation might be a **more widespread feature** than we have identified"*

Geographic Market Segregation

A More Widespread Feature Than We Have Identified?



Interpreting ψ as required *Punishment* to Sustain Collusion

1. We take the ψ's estimated in the preceding application.
2. Under a collusive agreement, side payments (or punishments) can rationalize the fact that operator l is in garage j, instead of operator i as our model predicts.
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3. Relate the ψ's to theory when collusion more likely, to separate out signal from noise.
4. Results suggest that $\psi \geq 0$, or *punishment*
    - Is more likely when there are fewer firms in the market
    - Increases during sustained periods without entry
    - Decreases when firms enter the market
    - Is higher for more isolated garages enjoying greater local monopoly rents

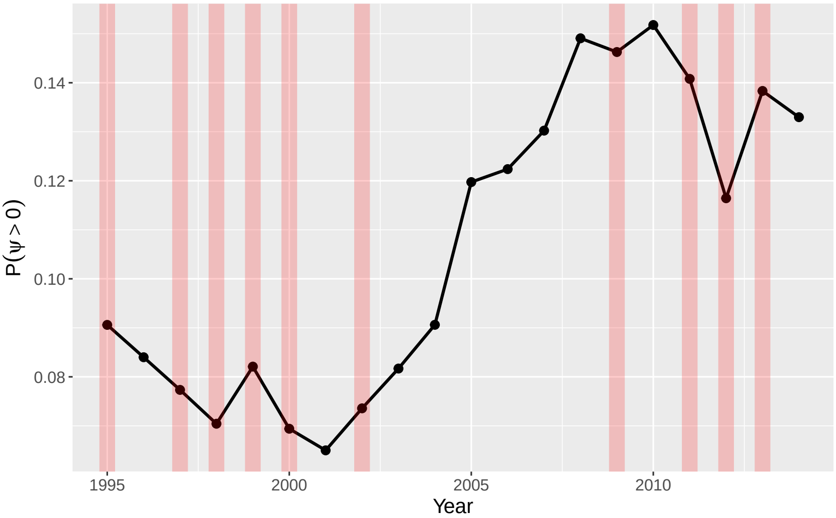
Theory: easier to collude in market with fewer firms

	$\psi : \psi > 0$	$\psi : \psi > 0$	$1(\psi > 0)$	$1(\psi > 0)$
(Intercept)	2.108^{***}	2.967^{***}	-1.377^{***}	-1.068^{*}
	(0.068)	(0.748)	(0.044)	(0.453)
No. alternatives	-0.002	-0.041	-0.058^{***}	-0.059^{**}
	(0.006)	(0.035)	(0.004)	(0.021)
Num.Obs.	8136	8136	71 775	71 775
R2	0.000	0.003		
R2 Adj.	0.000	0.000		
AIC	32 194.4	32 217.1	50 469.7	50 300.6
BIC	32 215.4	32 406.3	50 488.1	50 539.3
Log.Lik.	−16 094.175	−16 081.575	−25 232.855	−25 124.292
RMSE	1.75	1.75	0.32	0.32
Year-fixed effects?		✓		✓

- Fewer competitors = more gain per-firm and easier to coordinate
- Nr active firms varies over time, but finding consistent with year fixed effects

Theory: harder to collude when entry of new firms

Figure: Red bars indicate periods of high entry in market.



Spatial pattern of ψ measure

- More punishment for garages that are more isolated from competitors
- Higher local monopoly rents $=$ greater incentive to protect position

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