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A Multiple Stakeholder Strategic Model of Collaboration and Participation in Urban Consolidation Centers

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A **large number of UCC implementations** indicate significant public interest in urban freight consolidation

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Selected EU Cases

Janjevic (2015)

Negative externalities of urban freight:

- Congestion / traffic (vehicle kilometers traveled)
- Pollutant / GHG emissions

Urban Consolidation Centers (UCCs) seek to realize efficiencies and mitigate negative externalities by

a) reducing the number of vehicles used and achieving higher **vehicle utilizations**, and

b) adopting more efficient **vehicle technologies**

(Browne et al., 2011; Cleophas et al., 2018)

However:

- In the E.U., of 150+ projects, fewer than 20 remained after the first decade of the 2000s

(INTERREG, 2009)

- "Is there life after subsidy for an urban consolidation centre?"

(Kin et al., 2015)

Several reasons are commonly cited as **key contributors** to the **long-term success or failure** of a UCC

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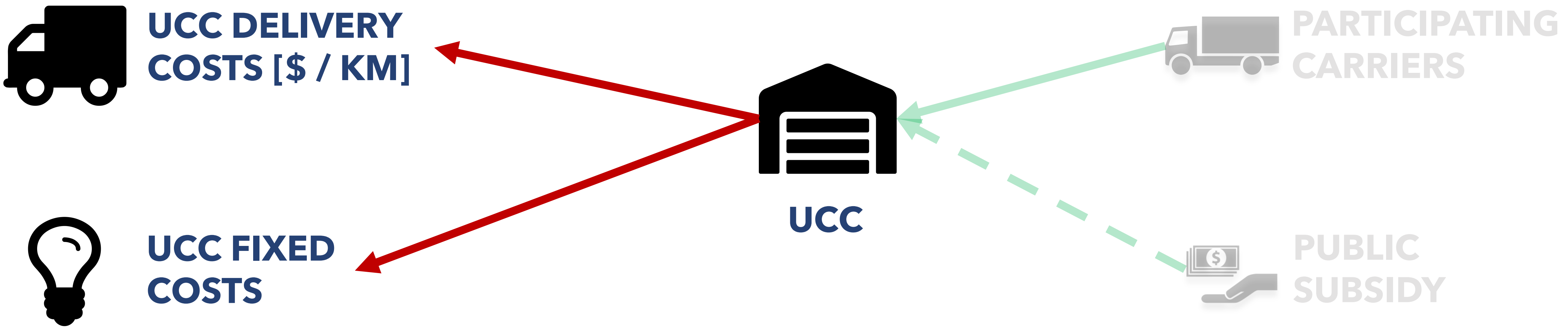
Participation [van Duin (2010)]	UCC charges a fee to carriers for transshipment and delivery. If fee is too high or its service is otherwise undesirable, it will not attract sufficient participation. **If participation is low, revenue is low.**
Location Choice [Browne (2005), Allen et al., (2007)]	UCC location must balance proximity to urban center (a determinant of UCC cost) and accessibility to carrier platforms (a determinant of UCC participation). **Poor locational choice harms UCC cost, participation, and policy effectiveness.**
Subsidy and Public Support [van Duin (2010)]	Financial support (subsidy) is expensive and politically unpopular; a successful UCC should create enough revenue to cover its (often high) costs. **Medium-term financial self-sufficiency is critical.**
Cost Sharing and Business Model [Janjevic et al. (2015), Marcucci (2008)]	A cost-sharing scheme must be devised to fairly balance charges levied on shippers according to their cost contribution to the UCC and the public benefit from consolidating their shipments. **Unfair sharing of cost and benefits will harm UCC adoption.**

Our model **aims to address each of these factors** in a simplified but comprehensive setting

Our aim is to model UCC feasibility with the intention of **minimizing data collection requirements** and **assumptions about carrier behavior**

Participation	Carriers participate if and only if **price offered by UCC ≤ own cost** of delivery
Location Choice	**UCC location is fixed** in each model instance (could become outer problem)
Subsidy and Public Support	**Initial subsidy** induces a coalition of carriers to join; the aim is to induce a sufficiently large coalition so that the UCC can be sustained in the long-term **without any continued subsidy**
Cost Sharing	**Carriers are charged proportional** to their marginal contribution of customer deliveries in UCC operation (other cost sharing models are possible)

A streamlined operating model for the UCC is proposed



UCC costs to cover:

- **Fixed cost per day** [input parameter]
- **Cost of conducting deliveries** [depends on coalition]
  - Assumed to vary with distance (km × cost per km → delivery cost)
  - Tour length estimated by continuum approximation *(cf., Daganzo (1990))*
  - No vehicle capacity or fixed expenses per vehicle assumed (for simplicity, can easily be extended)

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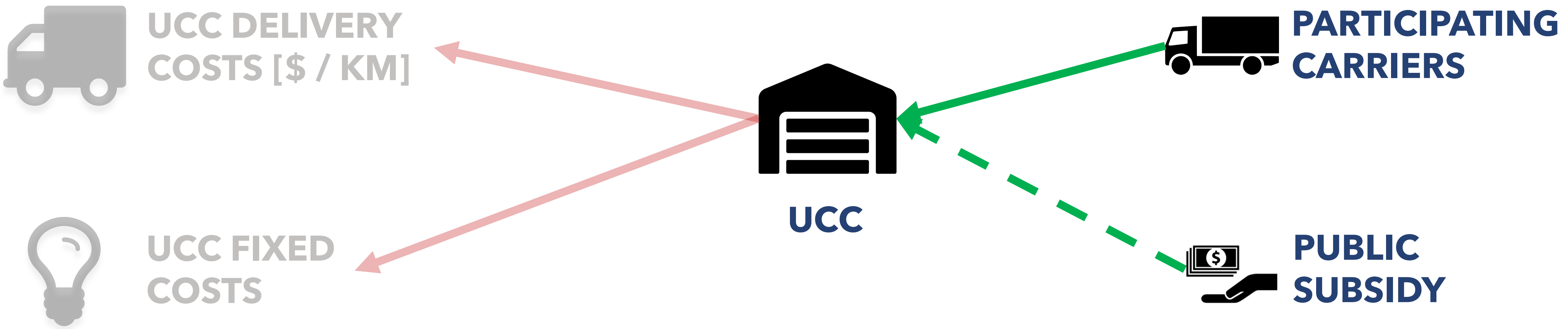


Sources of UCC revenue:

- **Carrier participation fees** [depends on coalition]
  - Set to cover fixed + variable operating **costs** of UCC – **subsidy**
  - Price (fee) offered to a **carrier N** ∝ the share of deliveries they would contribute *if* they joined:

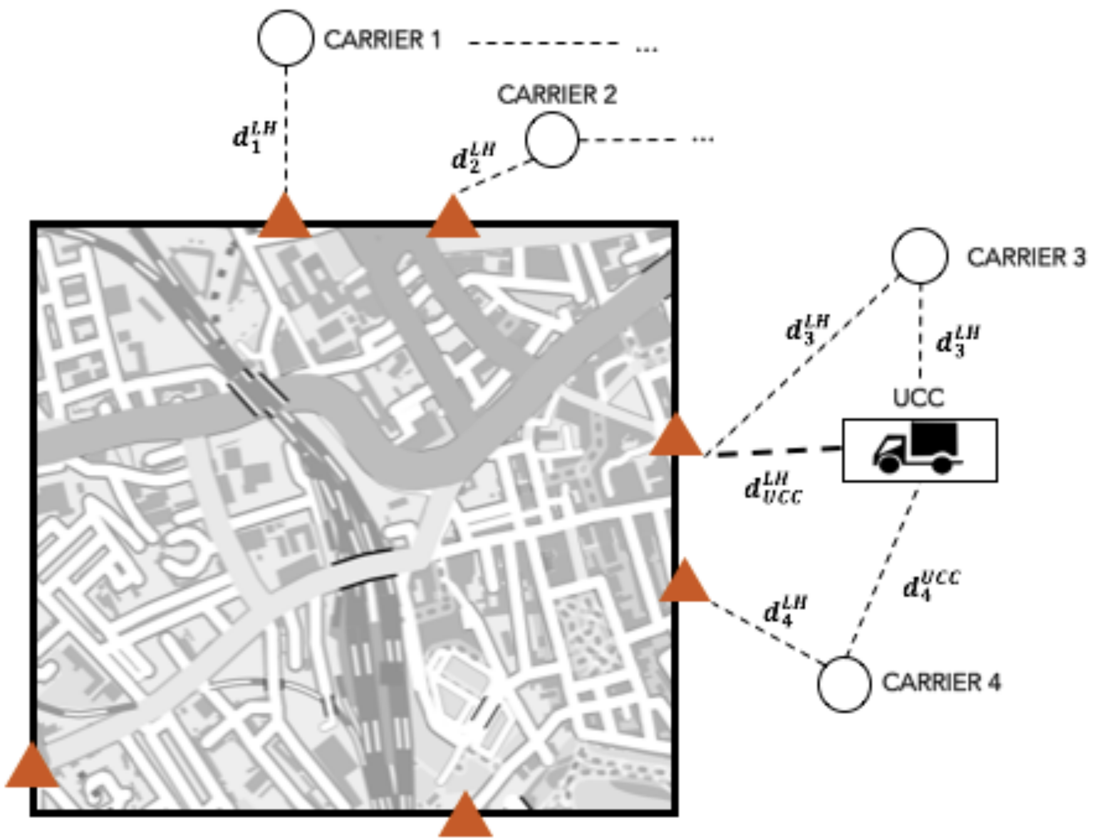
[Total UCC Costs - Subsidy] x [customers of carrier N / all customers in coalition]

A simplified network model reduces the need for data collection and explicit routing

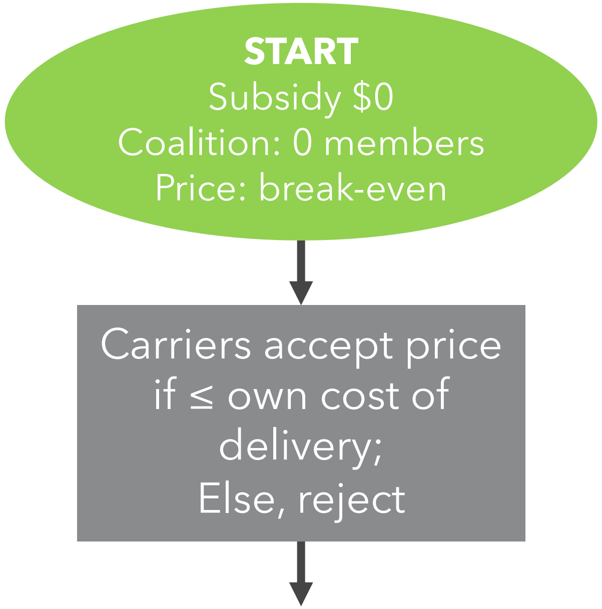
Game theoretical model of urban consolidation from Battaia et al. (2014)

- Extend to >2 carriers (any number accepted)
- Employ approximate vs. explicit routing

Carrier Data (non-financial, shared only with UCC)	• Distance to UCC • Distance to nearest entry point to urban region (continuum) • Number of customers
UCC Data (for each proposed location)	• Distance to nearest entry point to the urban region • Fixed costs
Fleet Parameters (global or carrier-specific)	• Cost per km traveled • May vary to reflect different vehicle technologies, etc.



An iterative heuristic is designed to model the rational decisions of each carrier as financial conditions change



This heuristic relies on the interaction of users through price:
- For a given price offered by the UCC, an equilibrium coalition of users exists
- The equilibrium must be re-calculated every time the price changes

The heuristic starts with a subsidy of zero.
- Each iteration increments the subsidy by some constant amount
- The subsidy lowers the break-even price UCC need to charge

Each iteration results in two equilibria:
- Equilibrium (1) consists of the number of users at the subsidized break-even price
- Equilibrium (2) consists of the number of users remaining once the subsidy is removed

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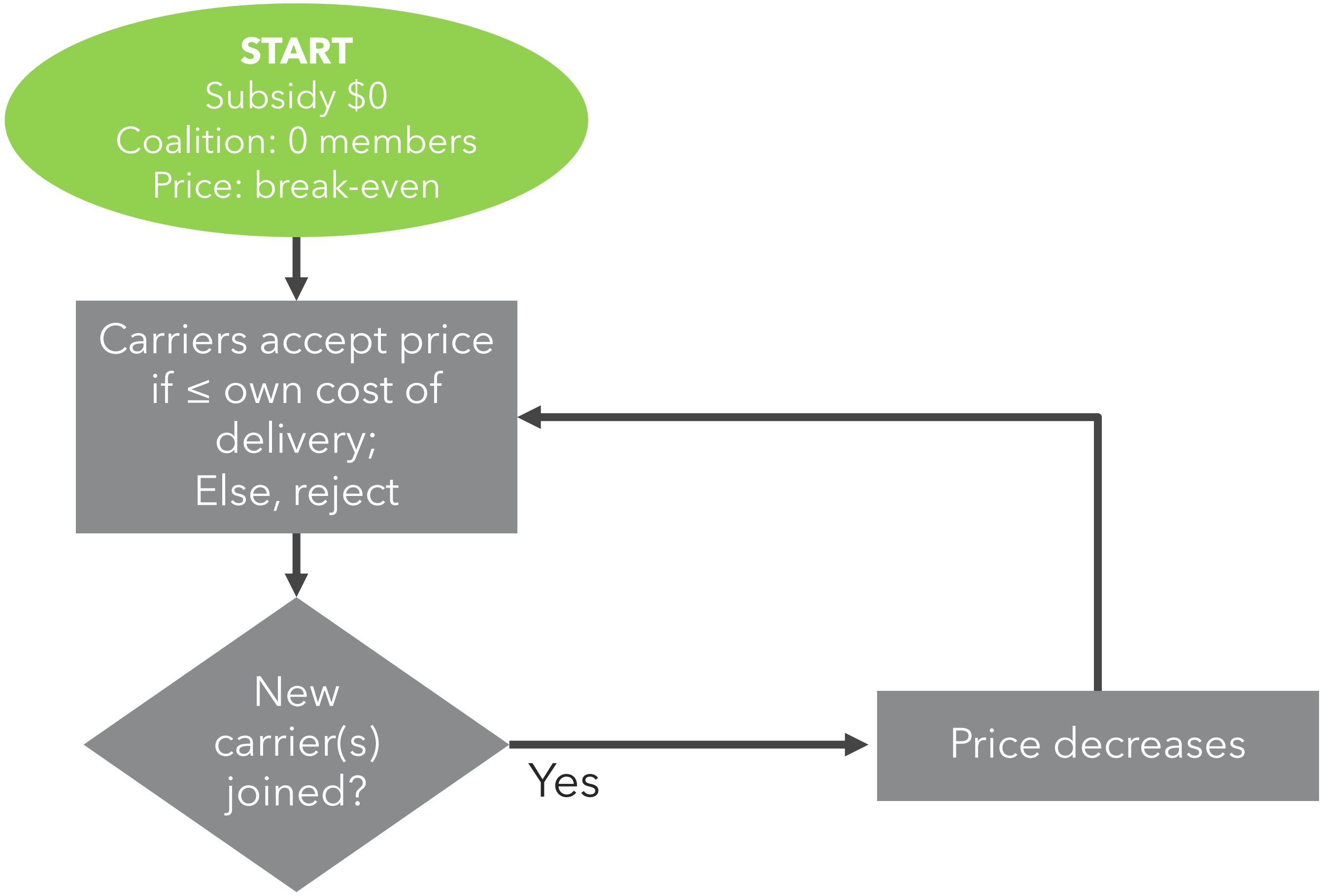

A price may be attractive to some carriers, who join the coalition.

- The break-even price decreases with every carrier who joins.
- This decrease may make the UCC attractive to additional carriers.
- This interaction proceeds until the coalition stabilizes.

An iterative heuristic is designed to model the rational decisions of each carrier as financial conditions change

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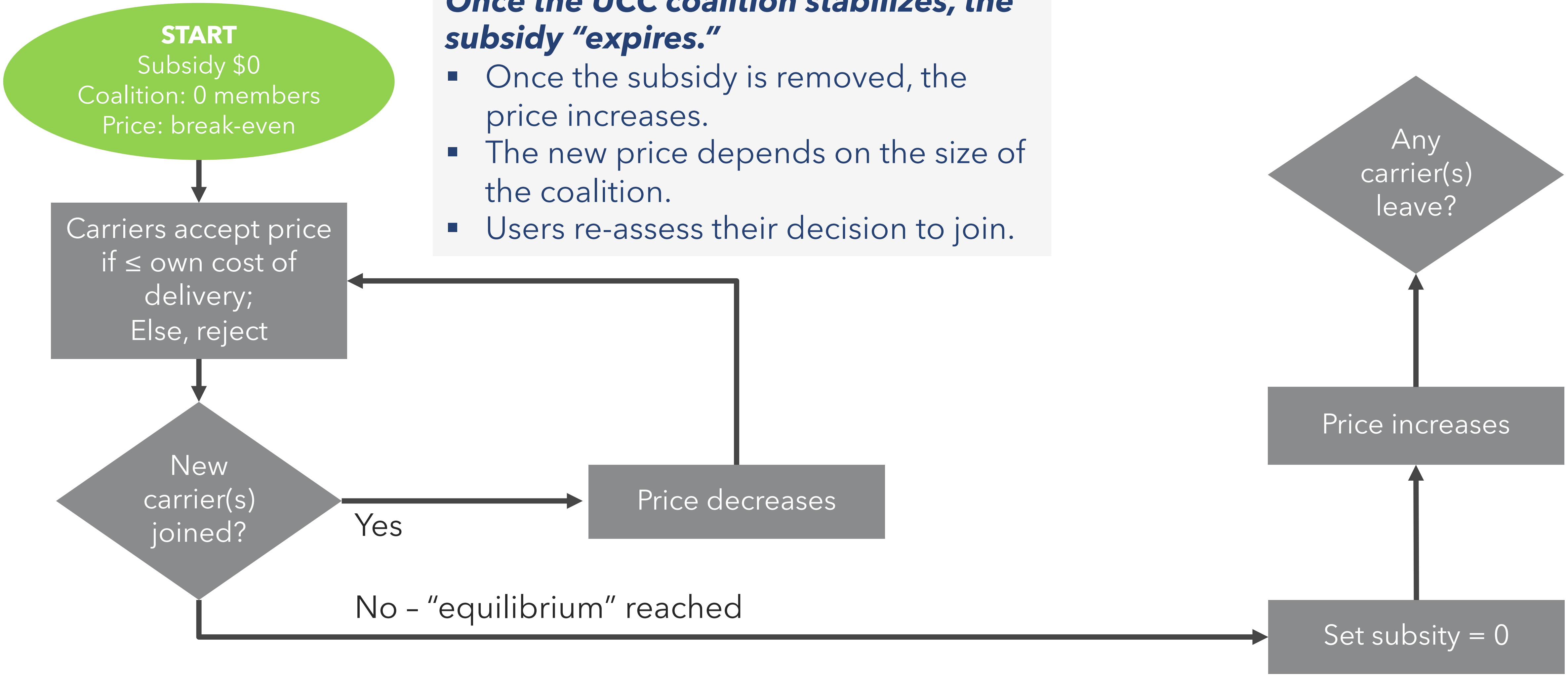
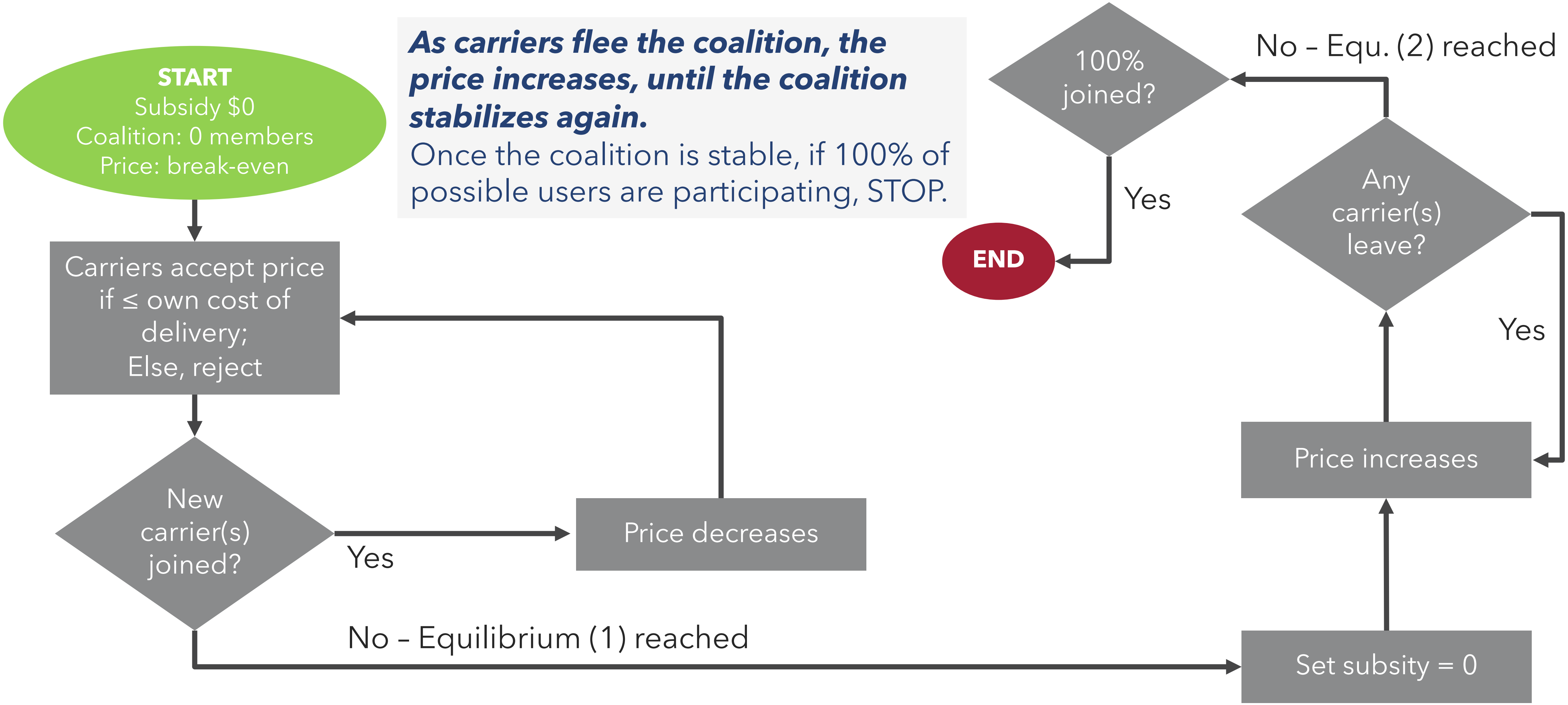
Once the UCC coalition stabilizes, the subsidy "expires."

- Once the subsidy is removed, the price increases.
- The new price depends on the size of the coalition.
- Users re-assess their decision to join.



An iterative heuristic is designed to model the rational decisions of each carrier as financial conditions change

As carriers flee the coalition, the price increases, until the coalition stabilizes again.
Once the coalition is stable, if 100% of possible users are participating, STOP.



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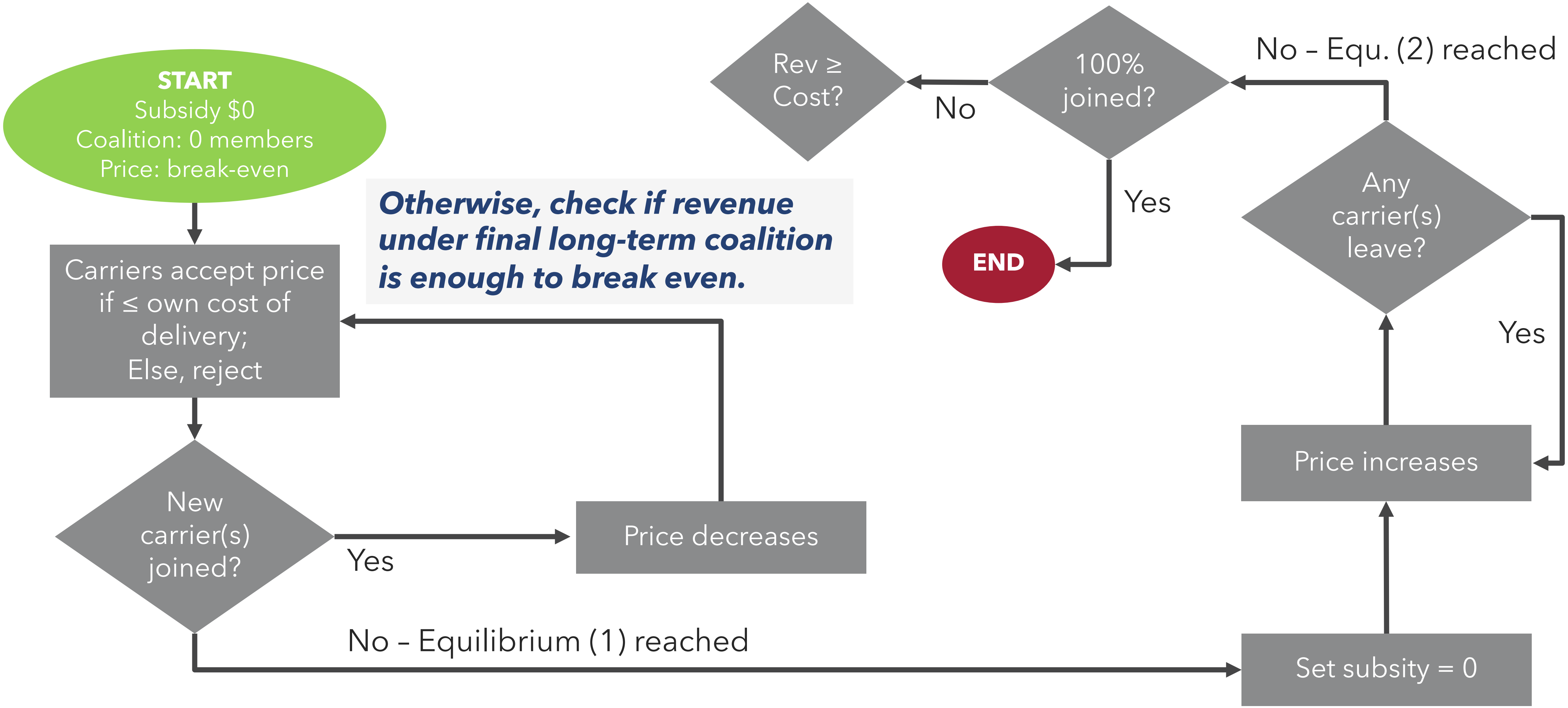

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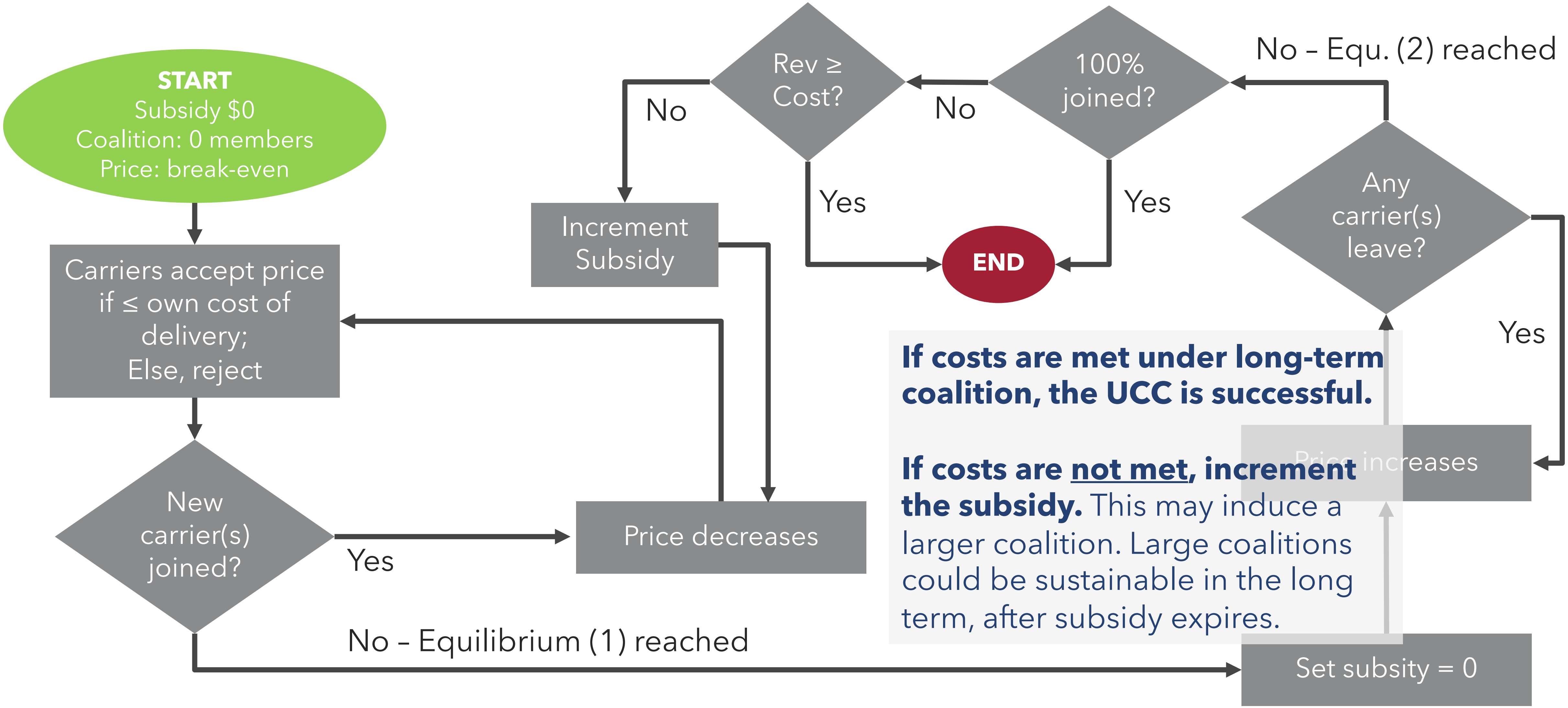
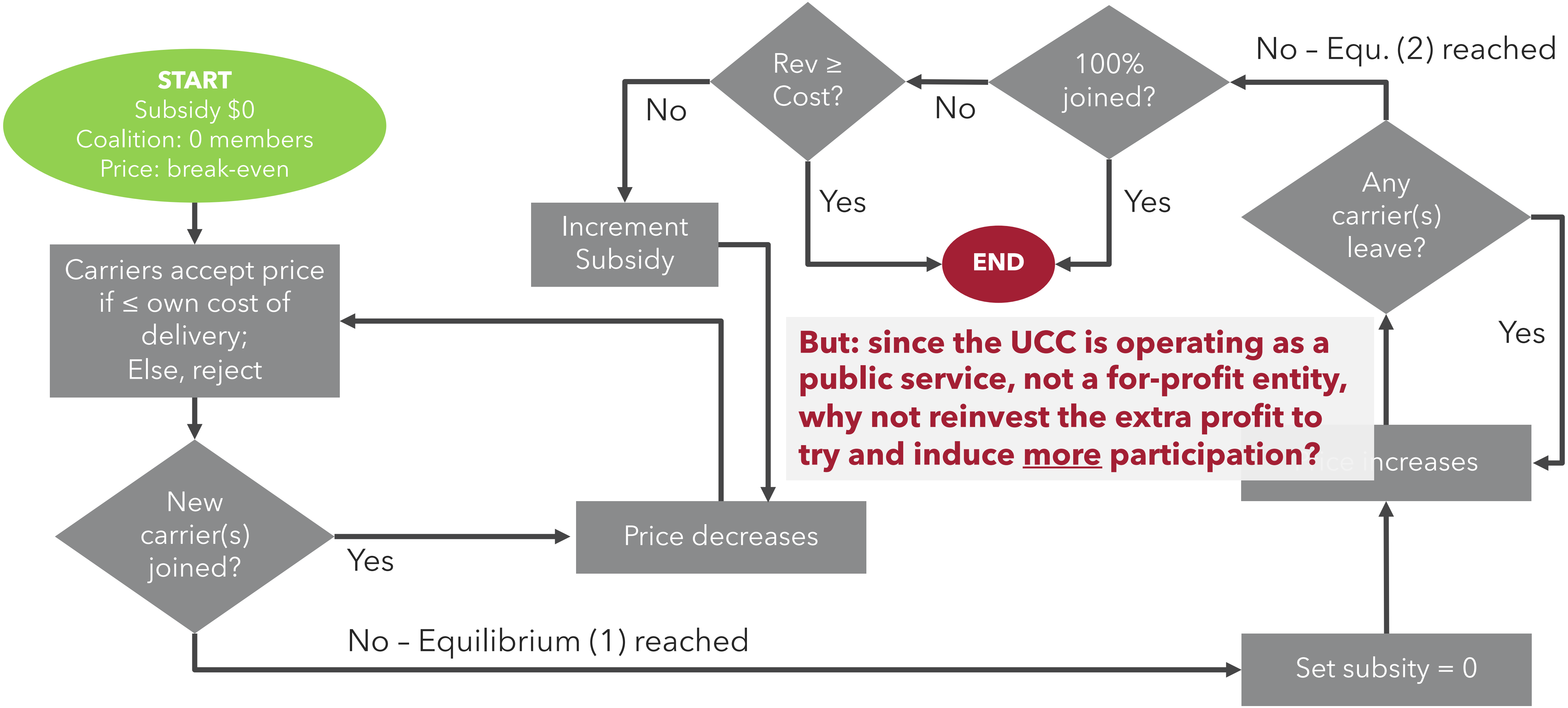


If costs are met under long-term coalition, the UCC is successful.

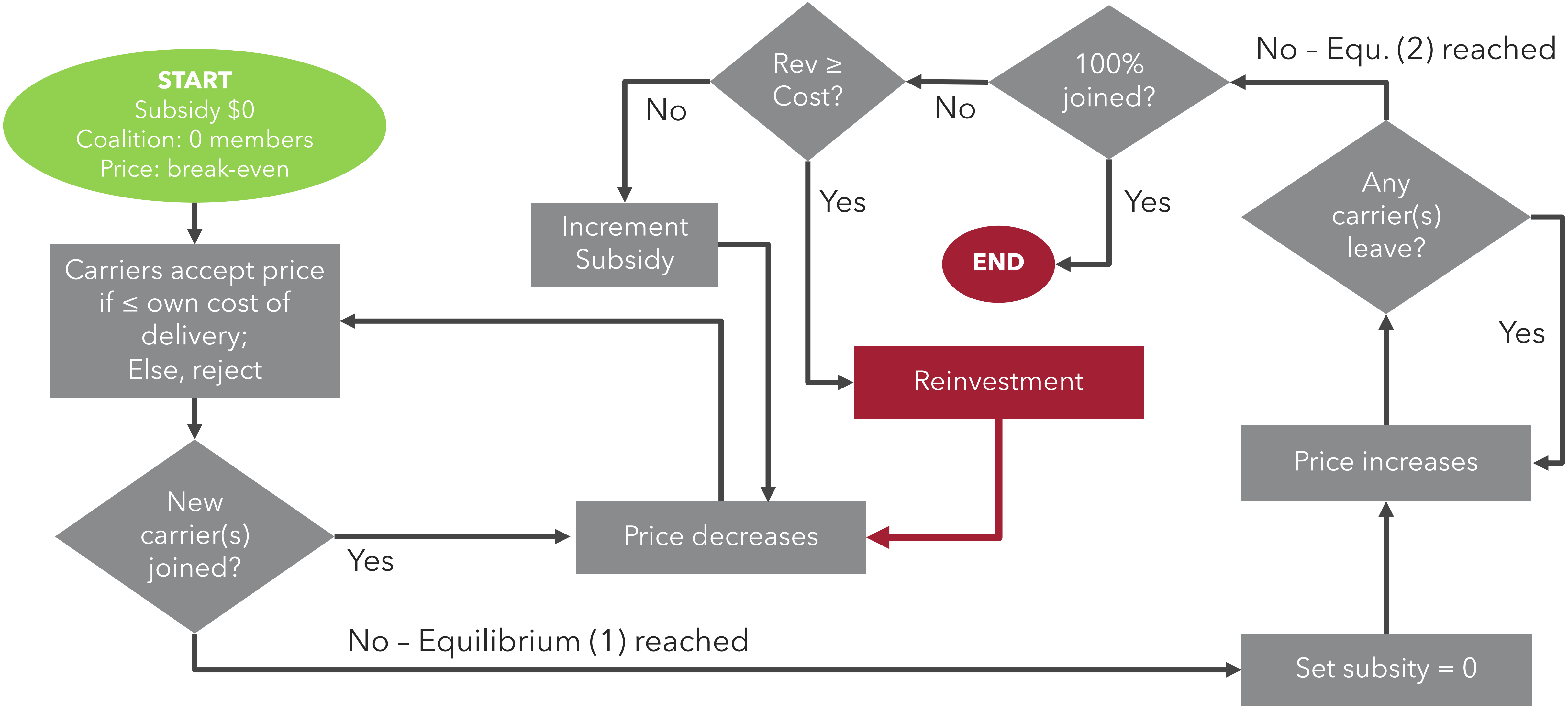
If costs are <u>not met</u>, increment the subsidy. This may induce a larger coalition. Large coalitions could be sustainable in the long term, after subsidy expires.

An iterative heuristic is designed to model the rational decisions of each carrier as financial conditions change



But: since the UCC is operating as a public service, not a for-profit entity, why not reinvest the extra profit to try and induce more participation?

An iterative heuristic is designed to model the rational decisions of each carrier as financial conditions change



The model is tested on **synthetic data inputs** intended to mimic reasonable network settings

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	Scenario A	Scenario B	Scenario C
Number of carriers	20	20	20
Avg. customers per carrier	**41.1** **~U(25, 60)**	**20.25** **~U(15, 25)**	**46.2** **~U(25, 60)**
Avg. carrier line-haul distance	8.8 km ~U(5, 15)	8.8 km ~U(5, 15)	8.8 km ~U(5, 15)
Avg. carrier-to-UCC distance	**17.7 km** **~U(5, 25)**	**17.7 km** **~U(5, 25)**	**29.6 km** **~U(15, 45)**
UCC line-haul distance	5 km	5 km	5 km
UCC fixed costs	$100 / period	$100 / period	$100 / period

Observation from Scenario A: Some networks require no long-term subsidy to induce a sustainable coalition

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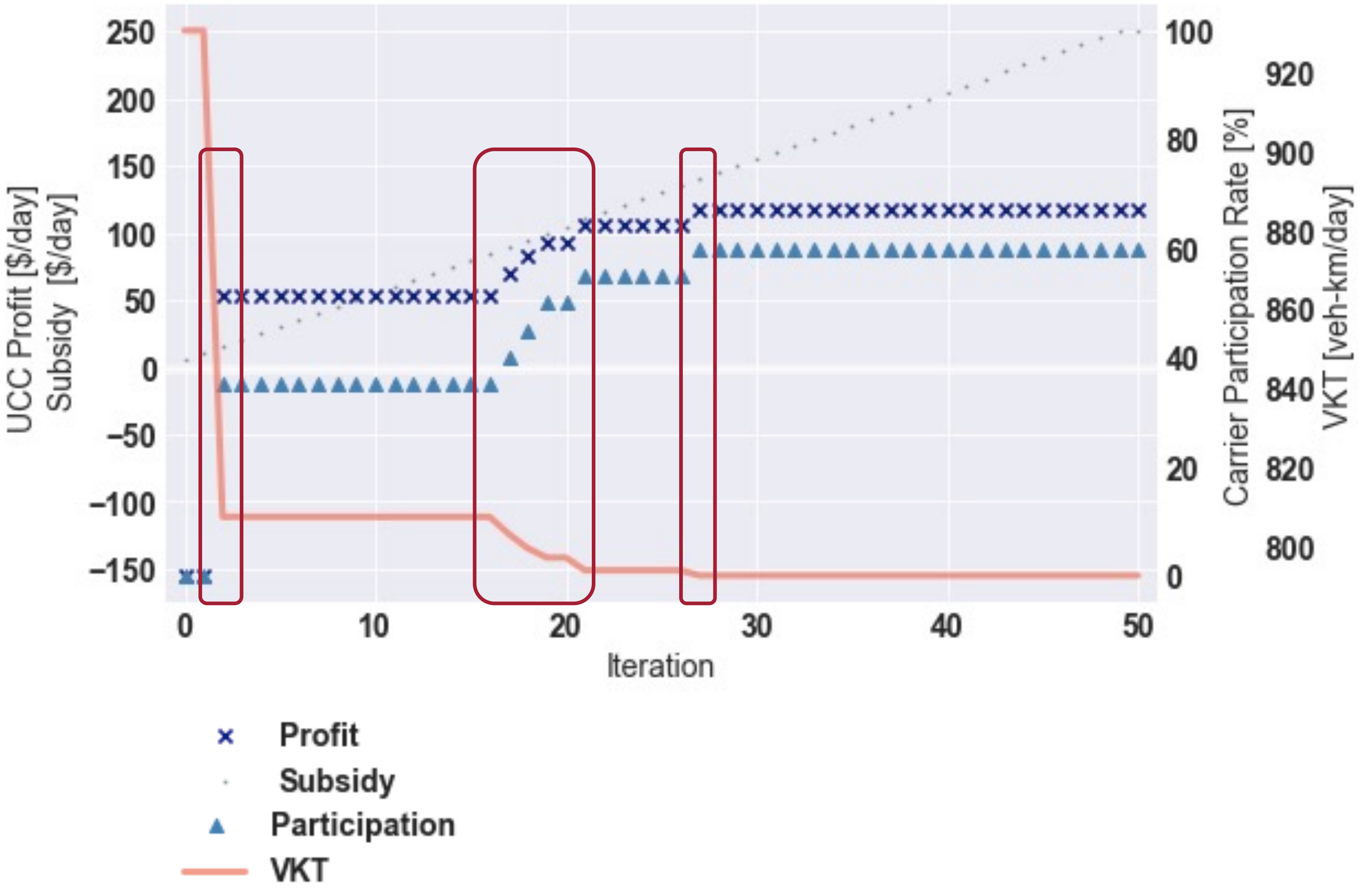
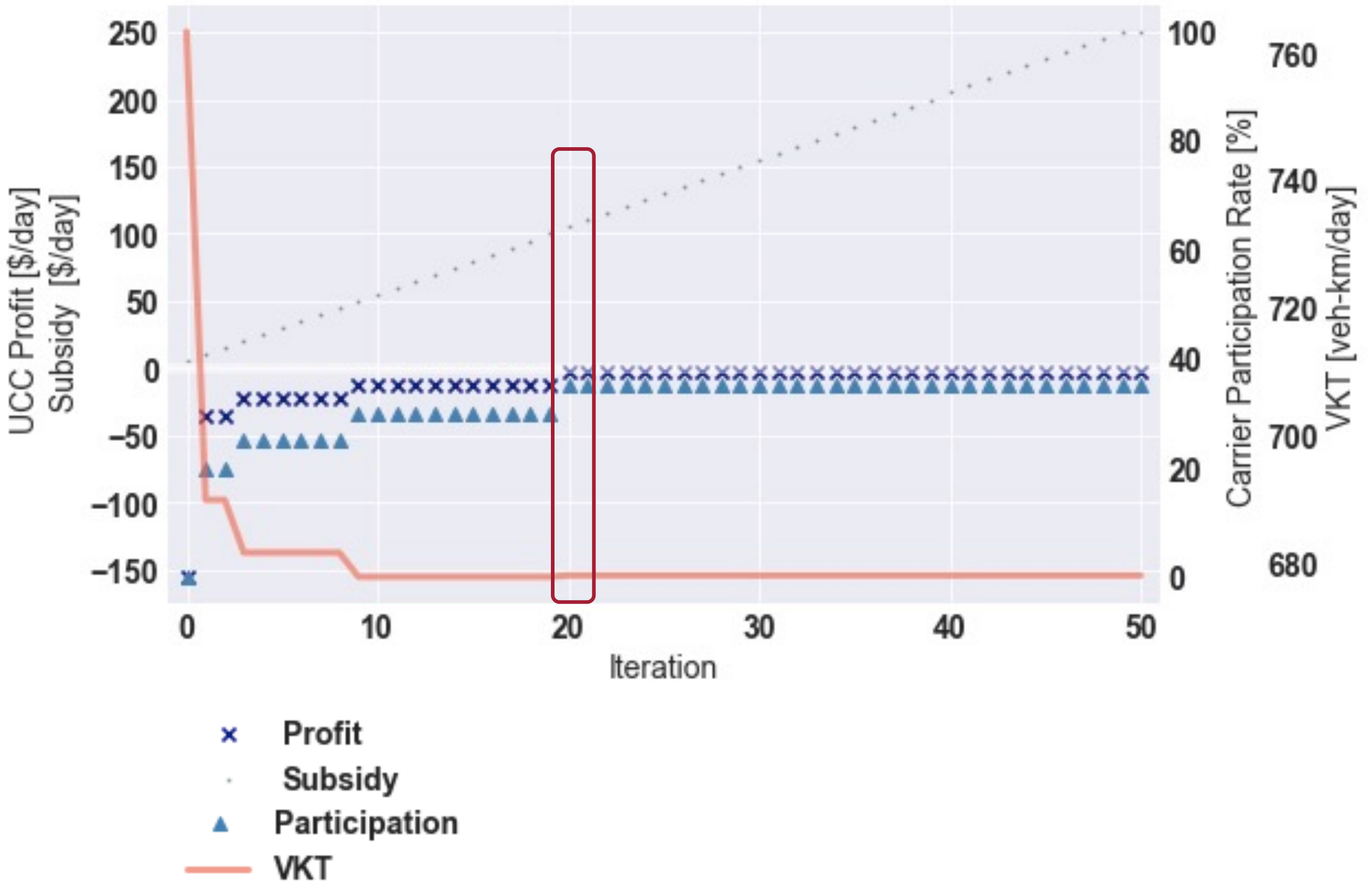


- After an initial subsidy is introduced, some carriers join
- This coalition is large enough to sustain the UCC operation once subsidy is revoked
- When subsidy is revoked, price increases but may still be lower than carrier's own cost of delivery

This UCC scheme is able to break even with positive profits once some initial (short-term) subsidy induces participation

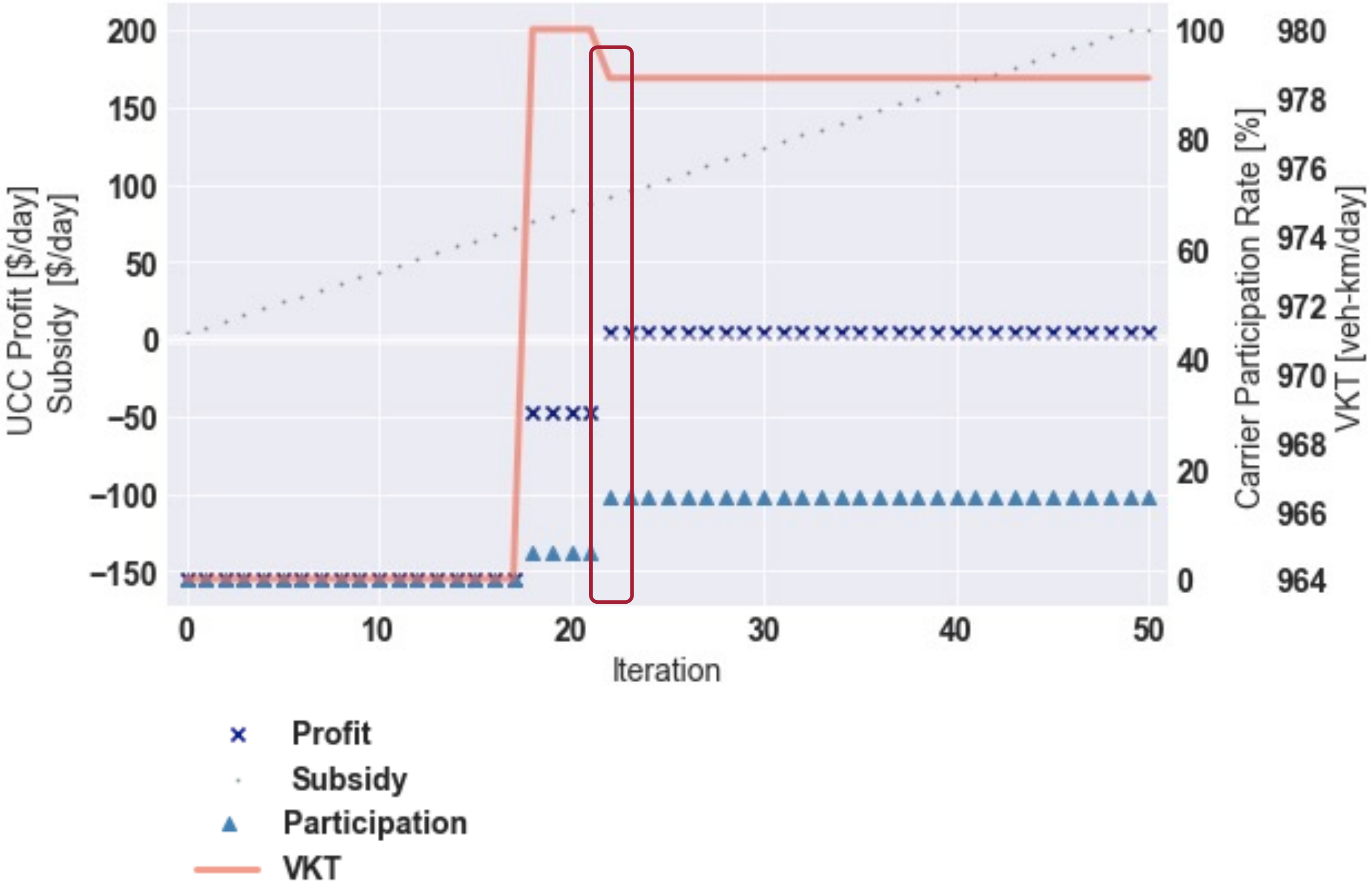
Observation from Scenario B: Some configurations cannot be financially sustainable, even with significant participation



- Initial subsidies cannot induce a coalition of participants large enough to meet costs
- This scenario is identical to (A) except for customer density
- Continuing past 50 iterations or to higher levels of initial subsidy produces the same result

Low customer density mitigates gains in routing efficiency realized by consolidation, making the UCC less competitive on a cost basis

Observation from Scenario C: Some configurations are financially feasible, but operationally inefficient



- From a financial perspective, this proposal is sustainable with about ~20% of the total carrier market captured
- However, from the perspective of total kilometers traveled, a modest ***increase*** is observed with higher consolidation

When the UCC is located far from carrier platforms and customer density is high enough, cost efficiencies from consolidation can make the UCC scheme financially viable, while it fails to meet its policy objective (VKT)

Our model captures **sufficient detail** about the UCC operating environment in a **concise framework**

General Findings

- **Network configuration** (i.e., locations) and **heterogeneous carrier profiles** (i.e., customer bases) have significant repercussions – not only on UCC feasibility, but also policy outcomes
- **Subsidy need not be permanent** if a large enough coalition can be induced to join (at least given this cost-sharing model)

Our model captures **sufficient detail** about the UCC operating environment in a **concise framework**

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Future Extensions

1. **Extension towards network design** by incorporating locational choices by the UCC and/or individual carriers

2. **Study of the effect of alternative cost-sharing schemes and revenue models** (modified expressions for UCC price setting)

3. **Systematic experiment design to devise recommendations for UCC design subject to context-specific parameter values** (demand characteristics, cost and time assumptions, city topology, road network features, etc.)

4. **Validation of recommendations based on real case-study data**

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Thank you.

Questions?

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