Optimizing the Last Mile

A Case Study in São Paulo, Brazil

São Paulo skyline
Source: vexels.com

Oswaldo Almonacid & Kenny Greene

Advised by Matthias Winkenbach & André Snoeck

Urban last-mile delivery in megacities is one of the most complex challenges in a global supply chain

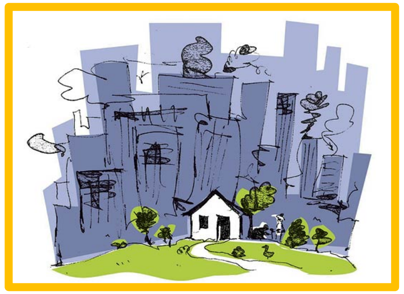
Factors to consider when designing a distribution network

Internal constraints

Number of facilities and facility capacity

Labor size, fleet size and vehicle types

External challenges



High customer expectations, demand fragmentation, urban agglomeration

Roadblocks, traffic congestion, inadequate road infrastructure, fuel price volatility

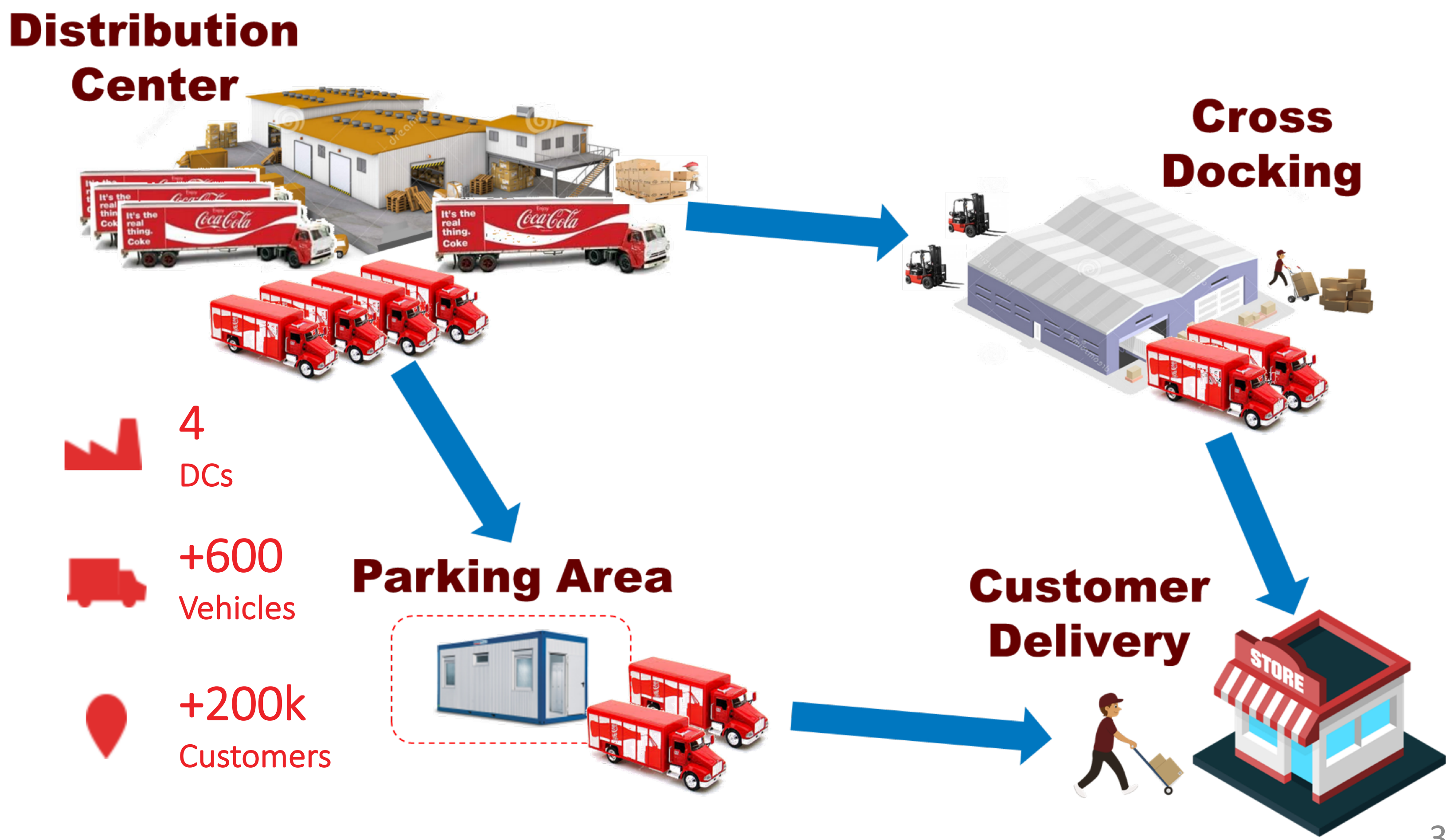
To tackle these challenges, the MIT Megacity Logistics Lab helps companies design better last-mile distribution networks

Project background

MIT MEGACITY LOGISTICS LAB

First project in  Bogotá and Cali

Current project in  São Paulo



And based on this background and challenges, the goal of the project is…

To design the most responsive, lowest-cost, last-mile distribution network for a set of different scenarios in emerging markets

How do we reach this goal?

Methodology

1. Data Collection and Processing
2. Optimization Model
3. Scenario Analysis

How do we reach this goal?

Methodology

1 — **Data Collection and Processing**

2 — Optimization Model

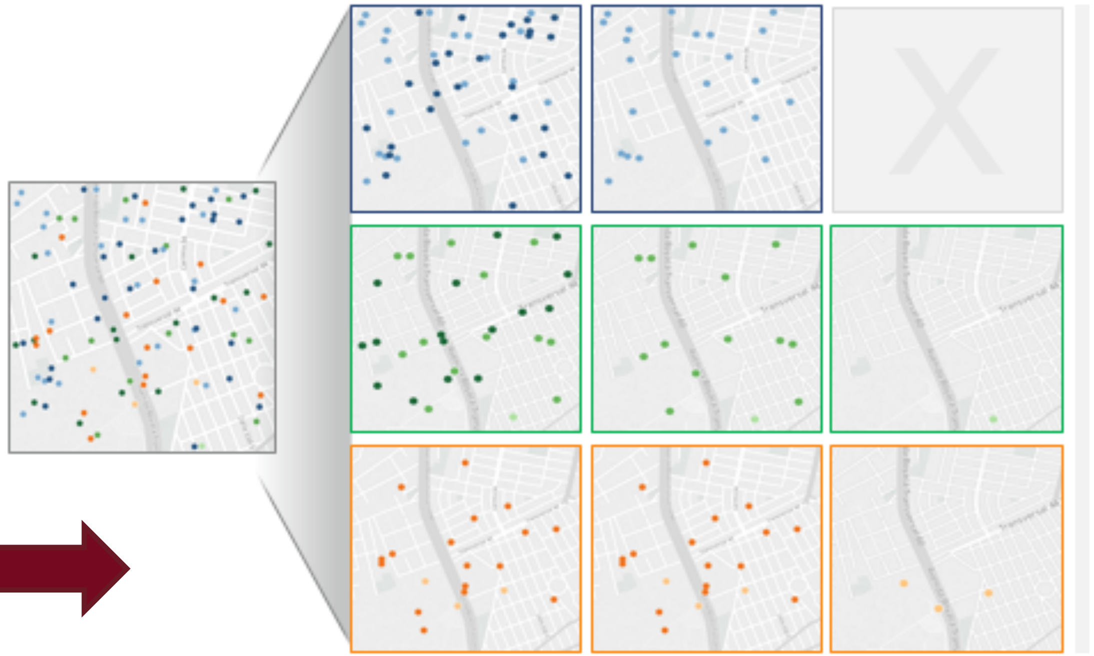
3 — Scenario Analysis

Parameter Values for the Model

- Cost and time parameters
- Vehicle and facility parameters

Demand Data Collection

Definition of Pixels



How do we reach this goal?

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$$\mathrm{Obj}(\mathbf{y}, \mathbf{x}, \mathbf{Q}, \mathbf{R})$$

$$= \sum_{f\in\mathcal{F}} K_f^R y_f + \sum_{v\in\mathcal{V}} \sum_{f\in\mathcal{F}} K_v Q_{fv}$$
$$+ \frac{1}{T}\Big(\sum_{t\in T} \sum_{f\in F} K_f^f y_f + \sum_{f\in\mathcal{F}} \sum_{v\in\mathcal{V}} \sum_{t\in T} K_v^R R_{fvt}$$
$$+ \sum_{i\in\mathcal{I}} \sum_{s\in\mathcal{S}} \sum_{p\in\mathcal{P}} \sum_{f\in\mathcal{F}(i)} \sum_{v\in\mathcal{V}(if)} \sum_{t\in\mathcal{T}} C_{ifvt}^{sp} x_{ifvt}^{sp} + c_f^i \gamma_{it}^{sp} \rho_{it}^{sp} x_{ifvt}^{sp}\Big)$$

Rent cost of activated facilities

Fixed cost of using owned vehicles

Daily rent costs of additional vehicles (not owned)

Fixed cost of facilities activated

Operational routing costs and handling costs to serve customers

Use of Approximation Formulas

Set of Constraints

Decision Variables

- Number of owned vehicles
- Number of rented vehicles
- Facility activated or not
- Allocation of pixel

How do we reach this goal?

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Goals of the scenario analysis:

- Validate robustness of baseline solution
- See where/when key cost/benefit tradeoffs occur
- Gain insights generalizable to similar last-mile networks
- Have fun/ exploratory analysis

The proposed scenarios are…

Baseline scenario

For meaningful comparisons

Driver overtime allowed

How many hours? Cost per hour?

Using outsourced drivers

Which modality offers most benefits?

Government regulations

Fuel taxes, vehicle size restrictions

Urban issues

Traffic, road blocks

Network analysis

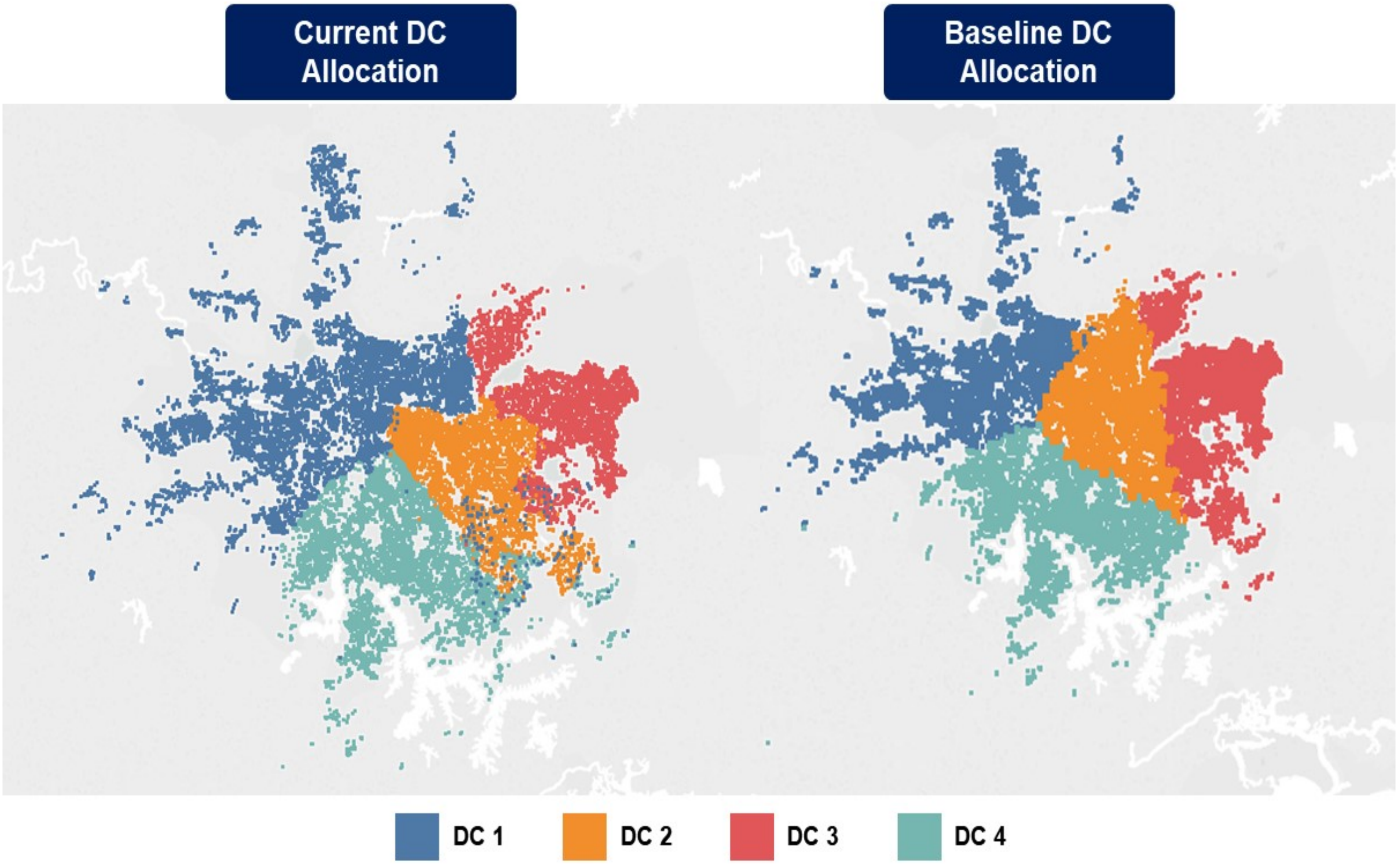
Which facilities does this network actually need?

Metrics

- **Costs**
  - Facility
  - Vehicle
  - Route
- **Quantity of Vehicles**
- **Distance**
- **Facility Usage**

Results: Baseline Scenarios

- **New DC service areas**
- **Satellite facilities not utilized**
  - If no fixed cost, this changes



Results: Overtime improves network performance

Baseline

Facility Name	Average Number of Cases Delivered per Tour	Average Distance from Facility to First Stop of Tour (km)	Average Cost per km (R$)	Average Cost per Delivery (R$)	Average Cost Per Case Delivered (R$)	Total Pixels Served	Customers Served	Vehicles Rented for Week
DC 1	100	10.00	75.00	75.00	5.00	1,293	5,000	243
DC 2	85	6.47	82.26	65.40	5.07	970	6,800	314
DC 3	113	9.79	91.91	79.07	4.00	857	4,023	200
DC 4	101	8.41	77.69	73.69	4.55	1,101	5,071	244

With 2 hours of OT

More productive routes

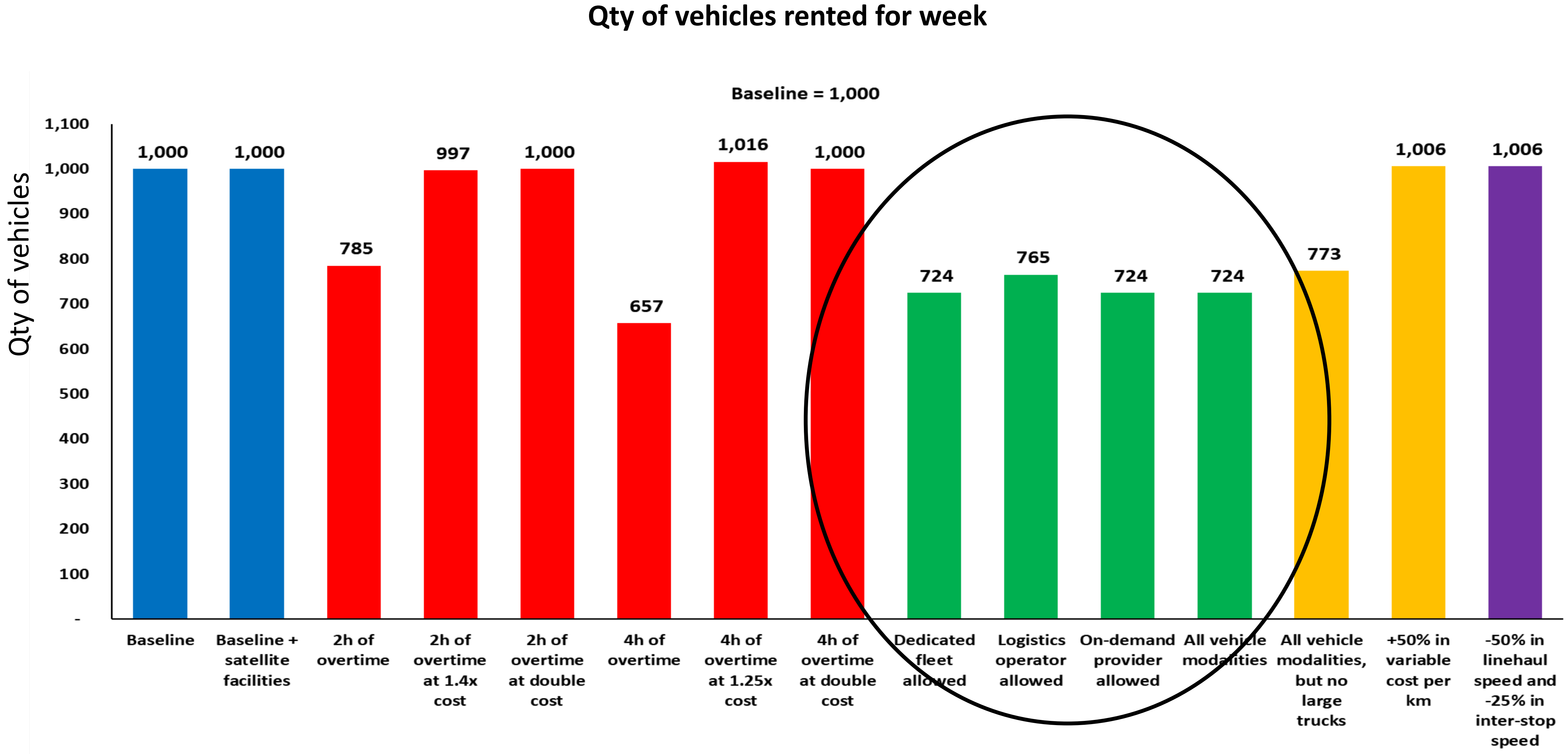
20% improvement

5% improvement

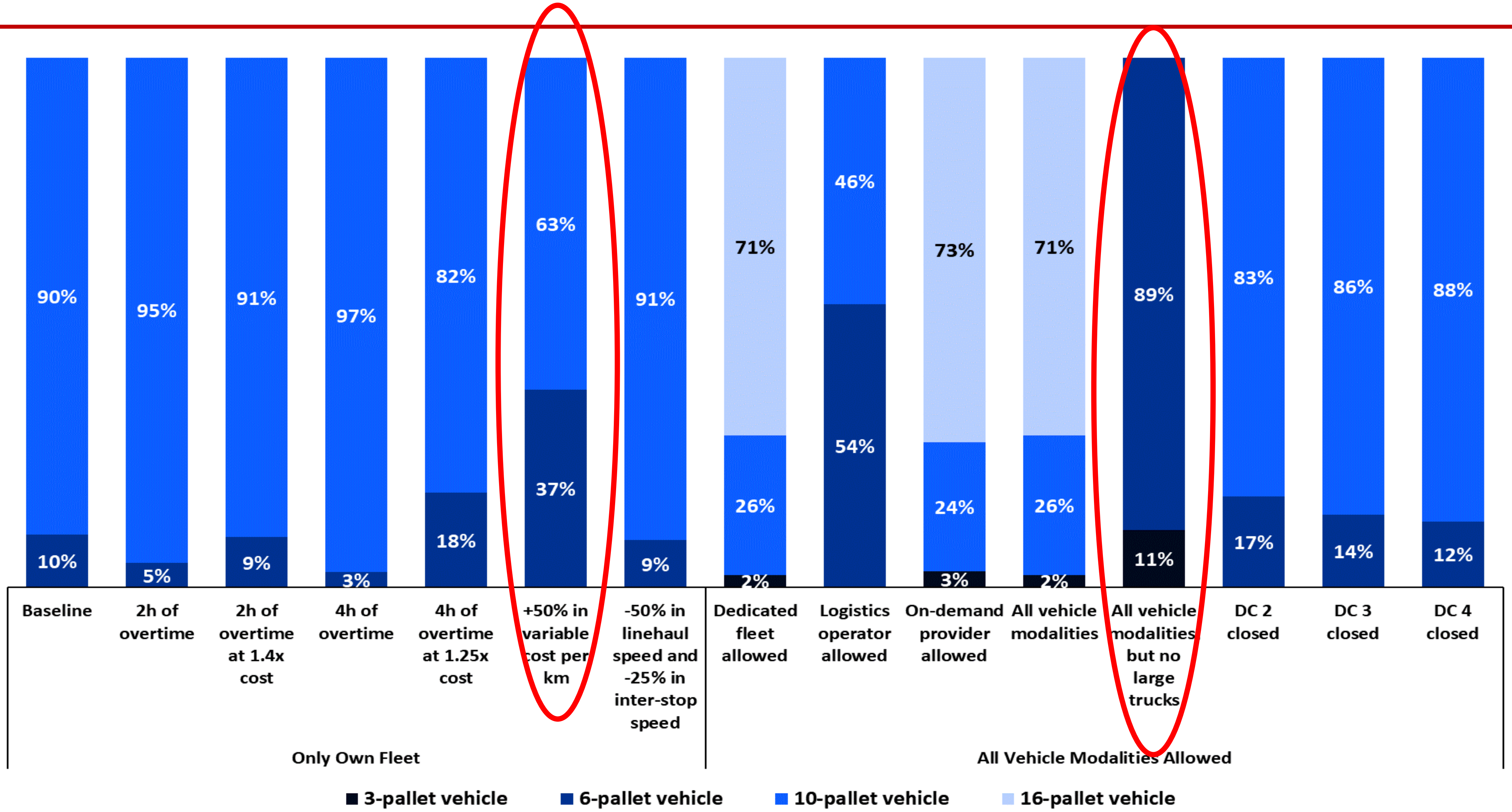
20% improvement

Facility Name	Average Number of Cases Delivered per Tour	Average Distance from Facility to First Stop of Tour (km)	Average Cost per km (R$)	Average Cost per Delivery (R$)	Average Cost Per Case Delivered (R$)	Total Pixels Served	Customers Served	Max Vehicles Used
DC 1	129	9.86	62.60	70.64	4.75	1,293	5,018	194
DC 2	112	6.52	67.67	62.90	4.89	970	6,745	250
DC 3	146	9.81	75.12	75.05	3.82	857	4,028	160
DC 4	131	8.41	64.31	70.24	4.37	1,101	5,103	195

Results: Outsourcing drivers reduces quantity of vehicles needed

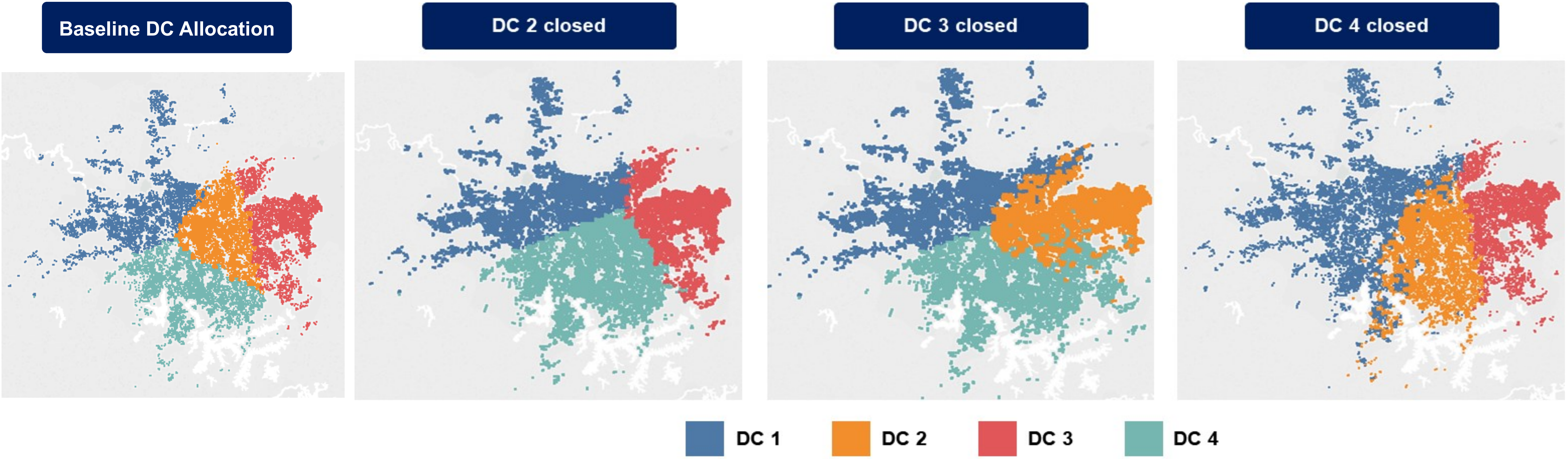


Results: government regulations change fleet composition



Results: urban issues do not disable the network

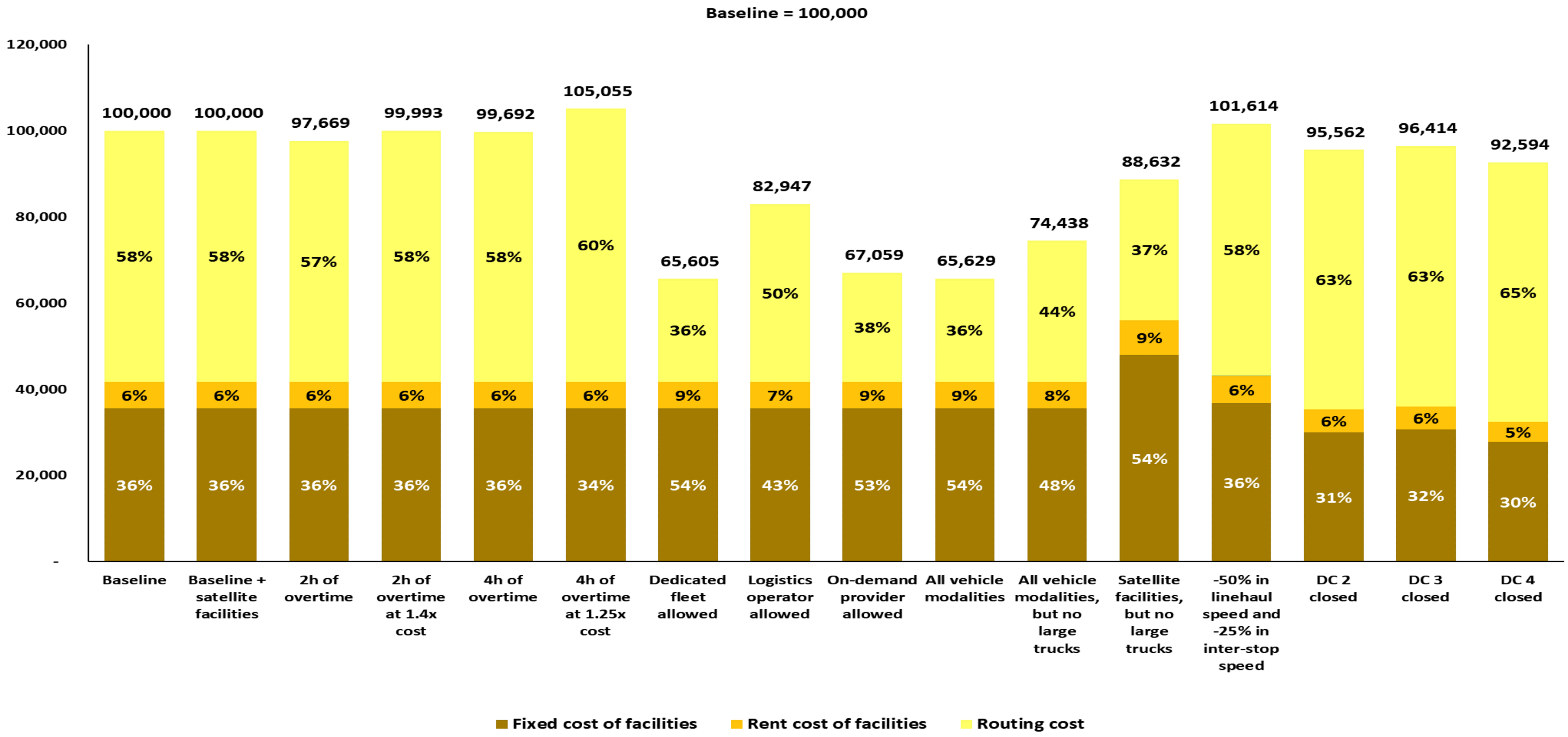
- **Traffic**
  - Costs increase by about 1%
- **Road blocks (assumed 1 DC was inaccessible)**



Results of Network Analysis: satellite facilities present challenges

- **Very tricky to force the model to consider a second echelon of facilities**
- **Potential reasons:**
  - Cost profiles of candidate facilities
  - Unconstrained number of vehicles
- **Opportunities for more analysis here**

Total costs: biggest improvements are in routing costs



Significant Findings & Future Extensions

Significant Findings

- Routing costs offer highest potential for cost savings
- Outsourced vehicle modalities are preferred
- Consider finding cheaper options for satellite facilities

Future Extensions

- **Constrained vehicle fleet size**
  - Determine optimal mix of modalities, sizes
- **Demand uncertainty**
  - Seasonality
  - ‘Balanced’ delivery week
- **Second-echelon**
  - What is the ‘perfect’ facility?

Questions?

Backup slide
Total Distance